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(54) **SKIN PANEL JOINT FOR IMPROVED AIRFLOW**

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**Related U.S. Application Data**

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(51) **Int. Cl.**  
**B64C 1/12** (2006.01)

(52) **U.S. Cl.** ..... **244/132; 244/131; 244/130**

(58) **Field of Classification Search** ..... None  
See application file for complete search history.

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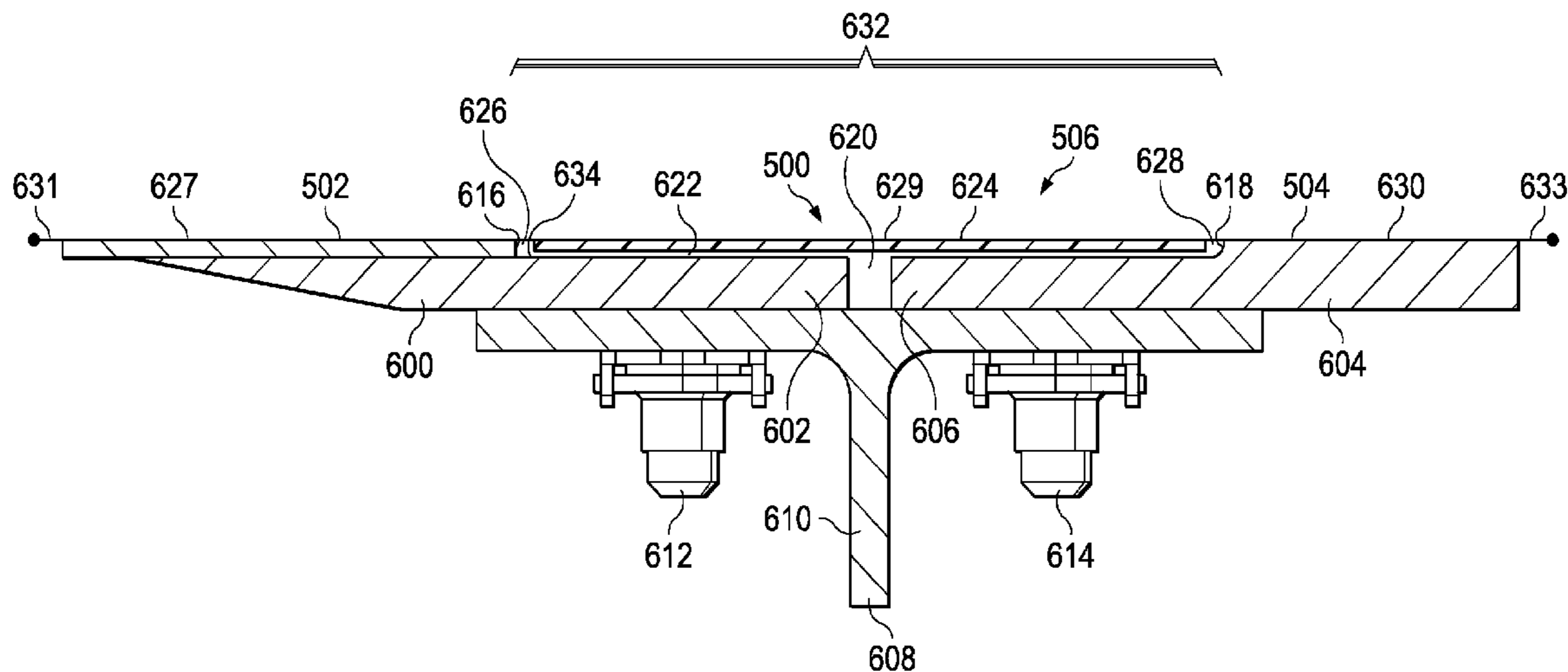
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(57) **ABSTRACT**

An apparatus may comprise a first skin panel having a first surface, a second skin panel having a second surface, a first flange located at an end of the first skin panel, a second flange located at an end of the second skin panel, and a strip having a third surface. The first skin panel may be located adjacent to the second skin panel such that the first flange and the second flange form a channel. The strip may be bonded in the channel. Fluid flow over the third surface of the strip, the first surface of the first skin panel, and the second surface of the second skin panel may have a desired state.

**20 Claims, 21 Drawing Sheets**



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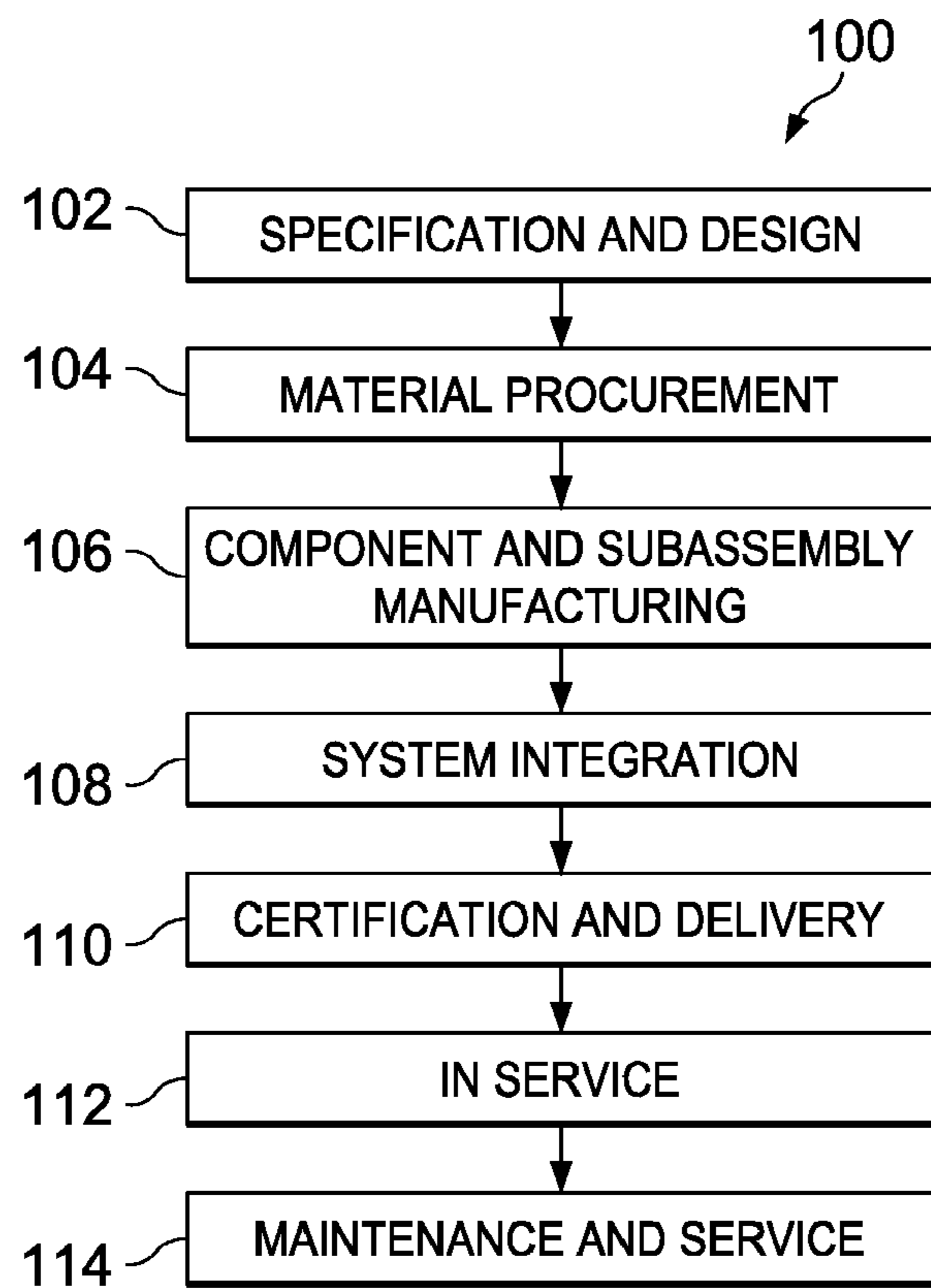


FIG. 1

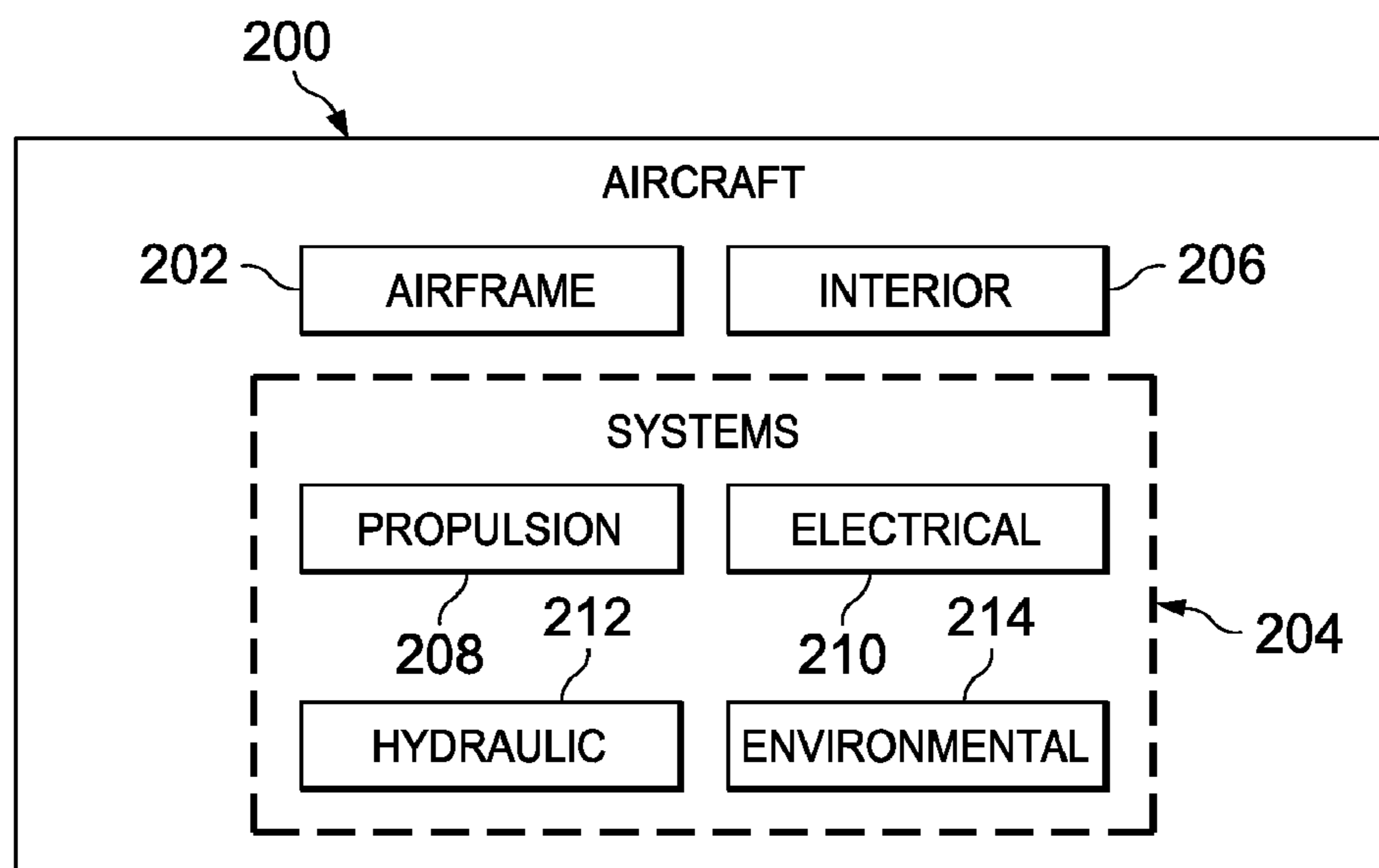
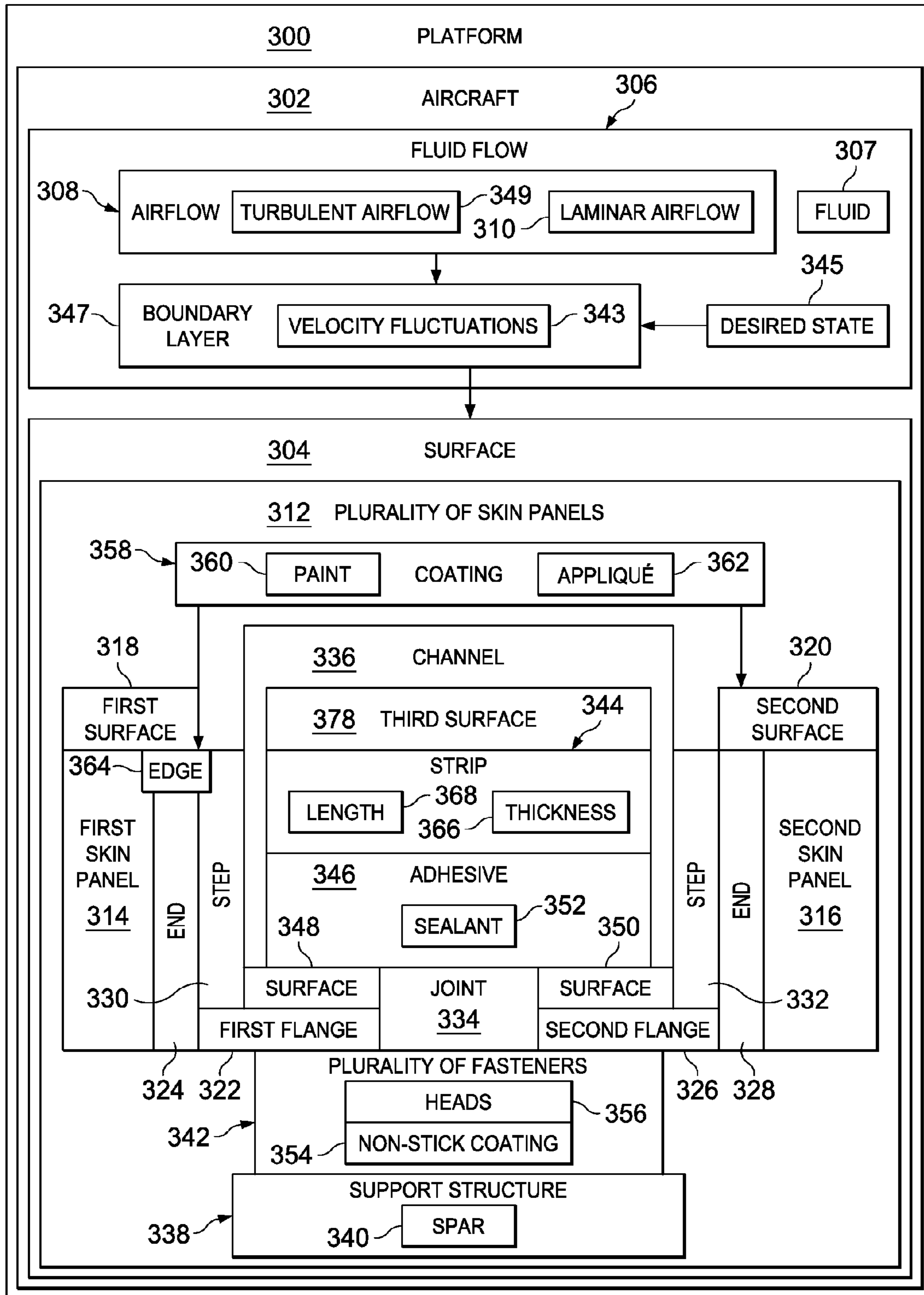
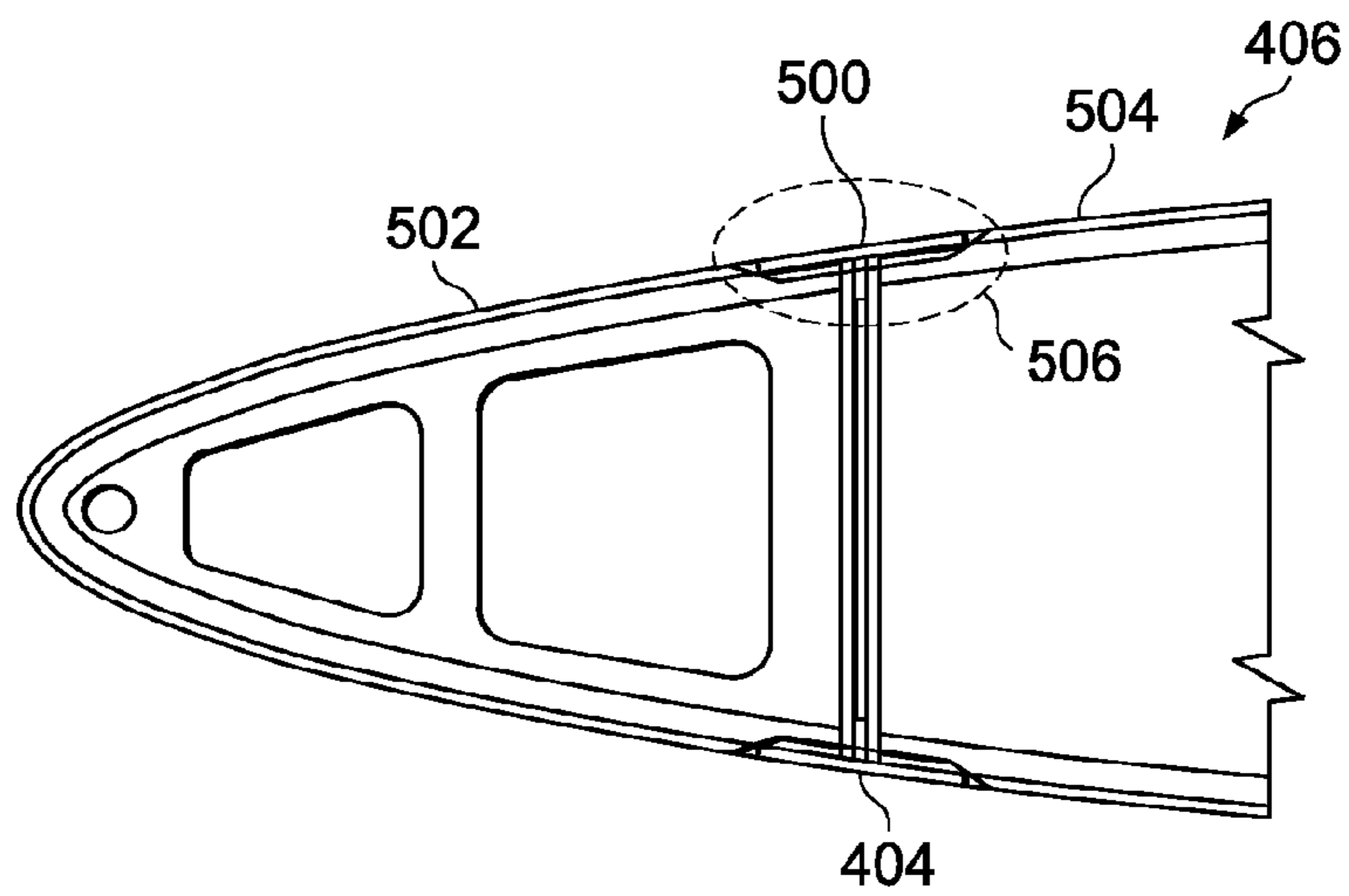
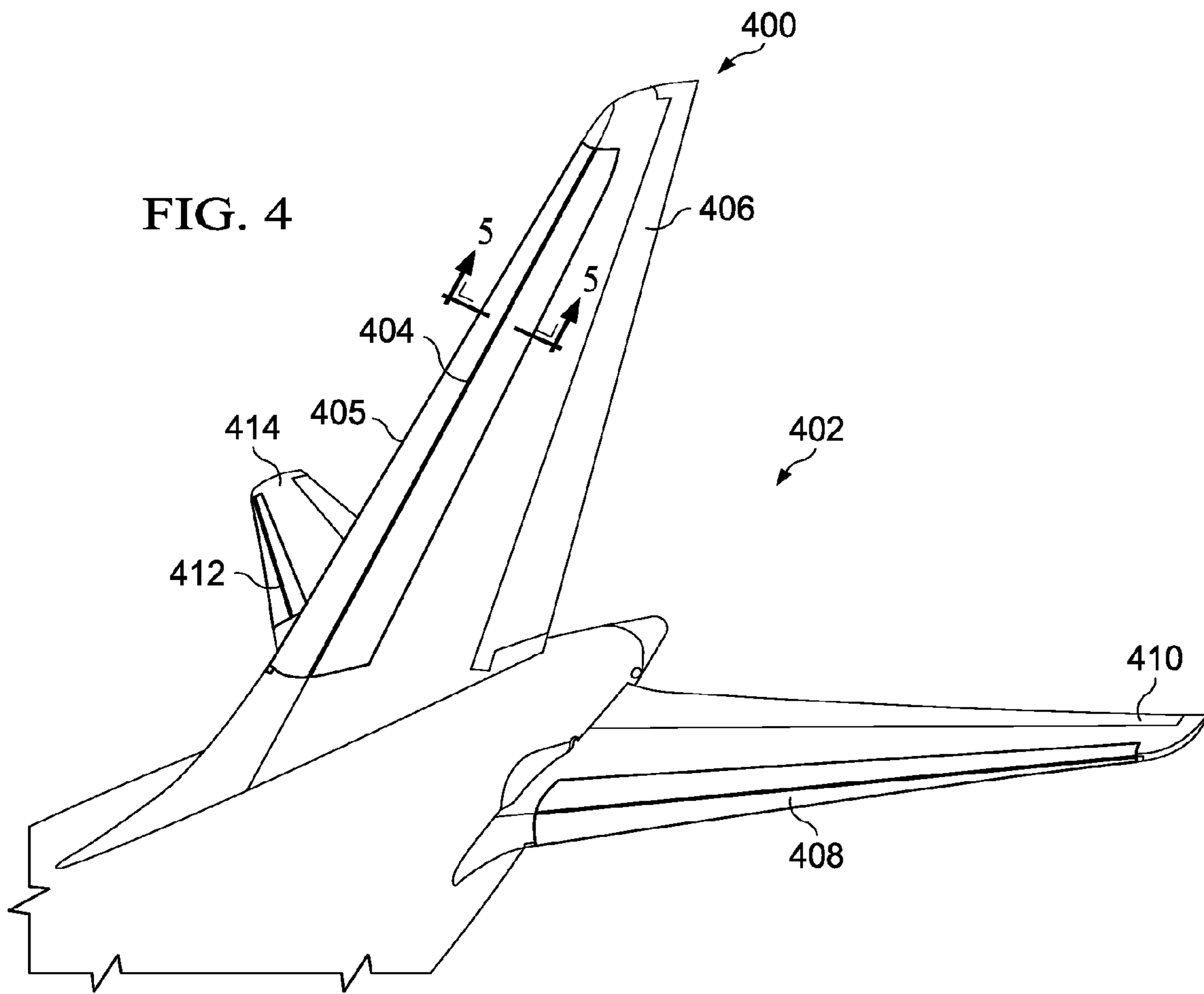


FIG. 2

FIG. 3







**FIG. 5**

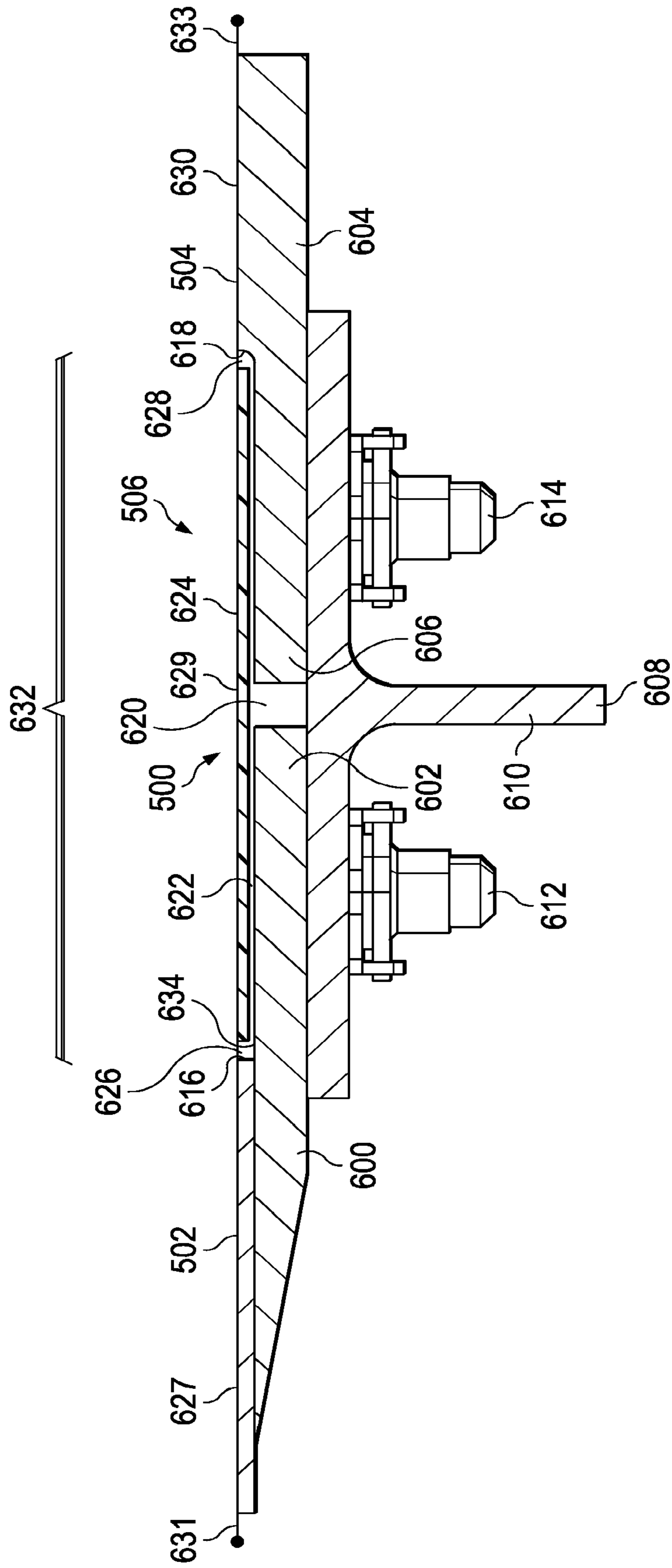
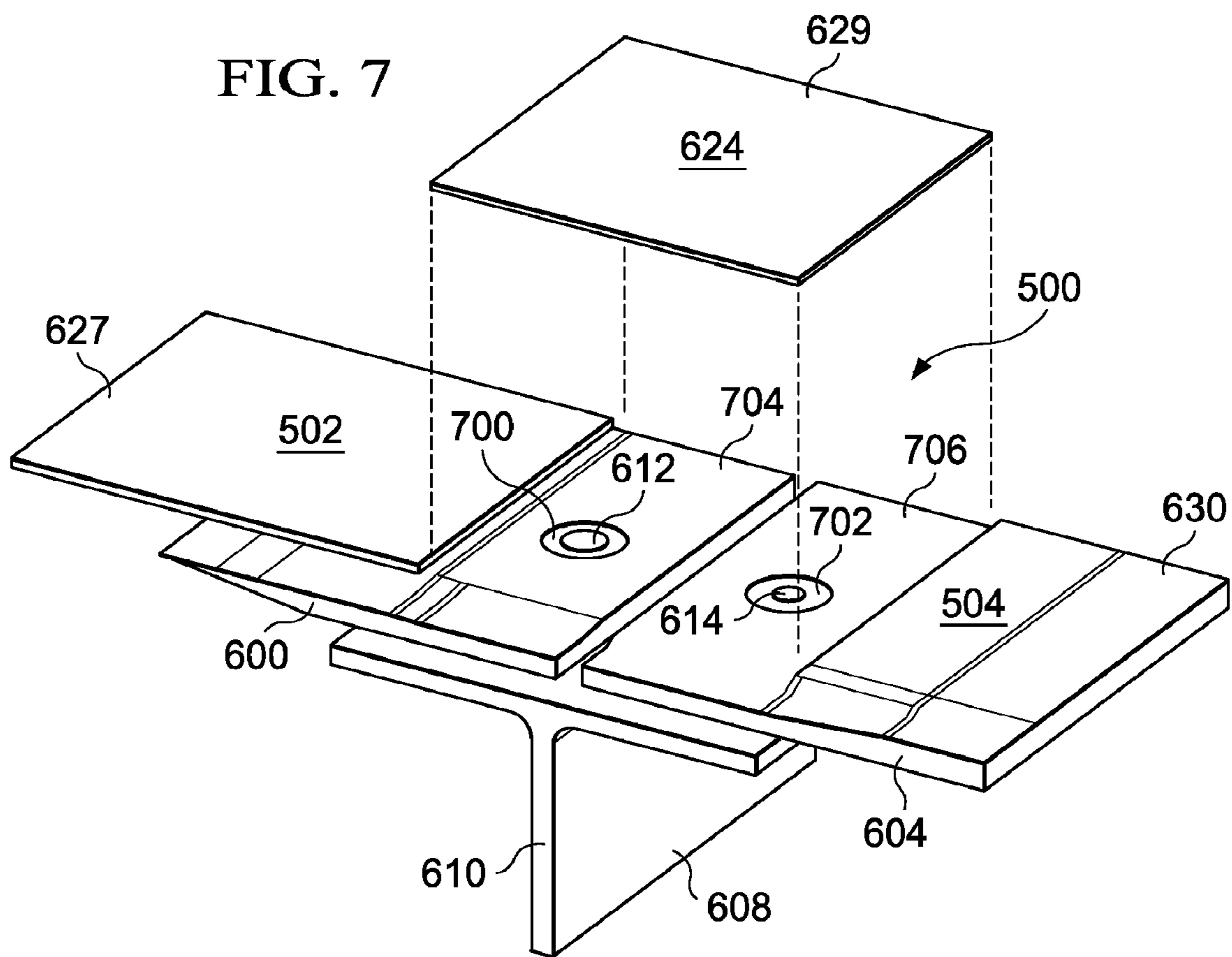


FIG. 6



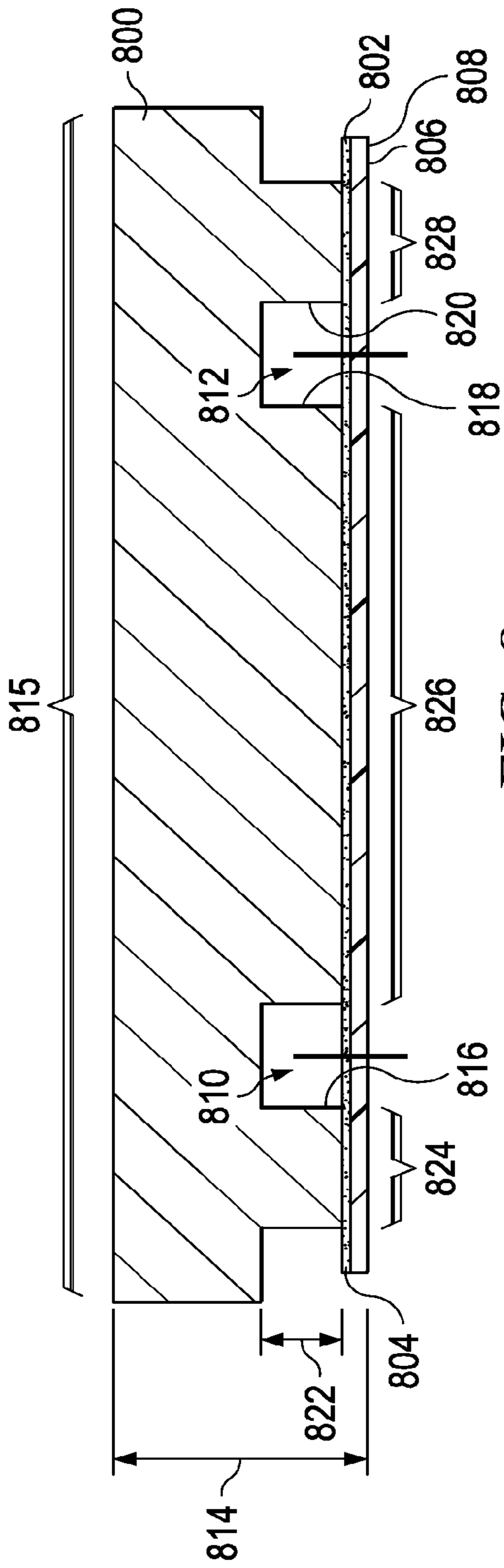


FIG. 8

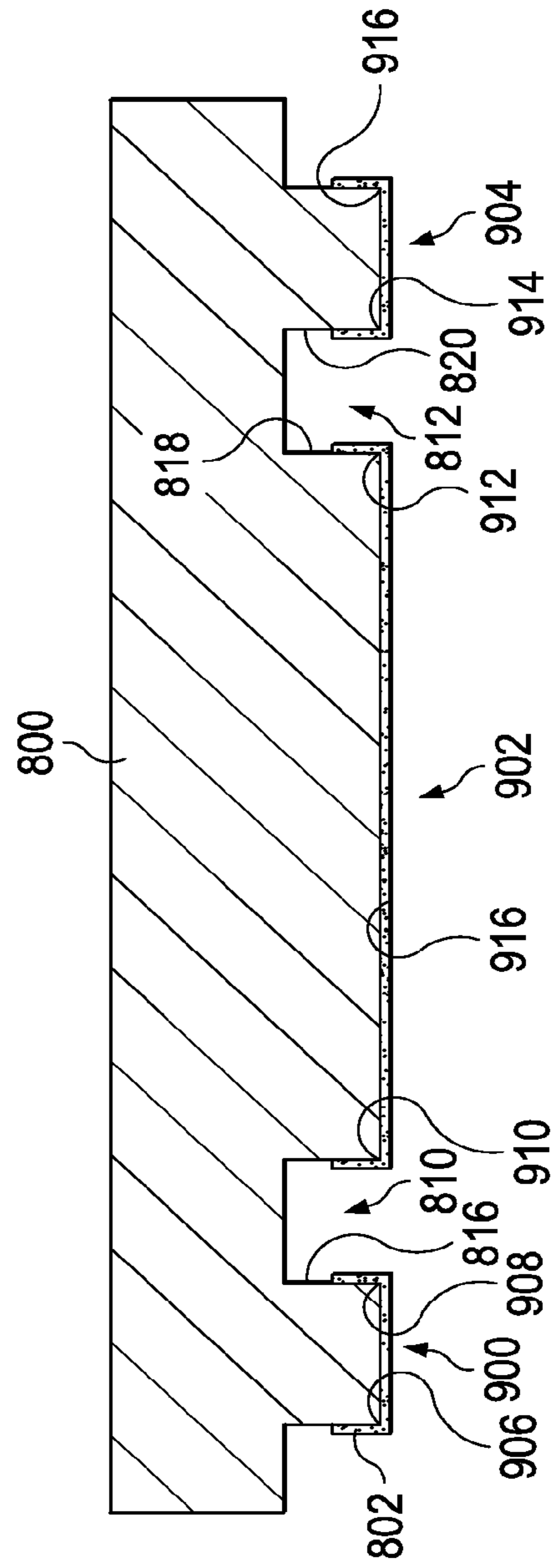


FIG. 9



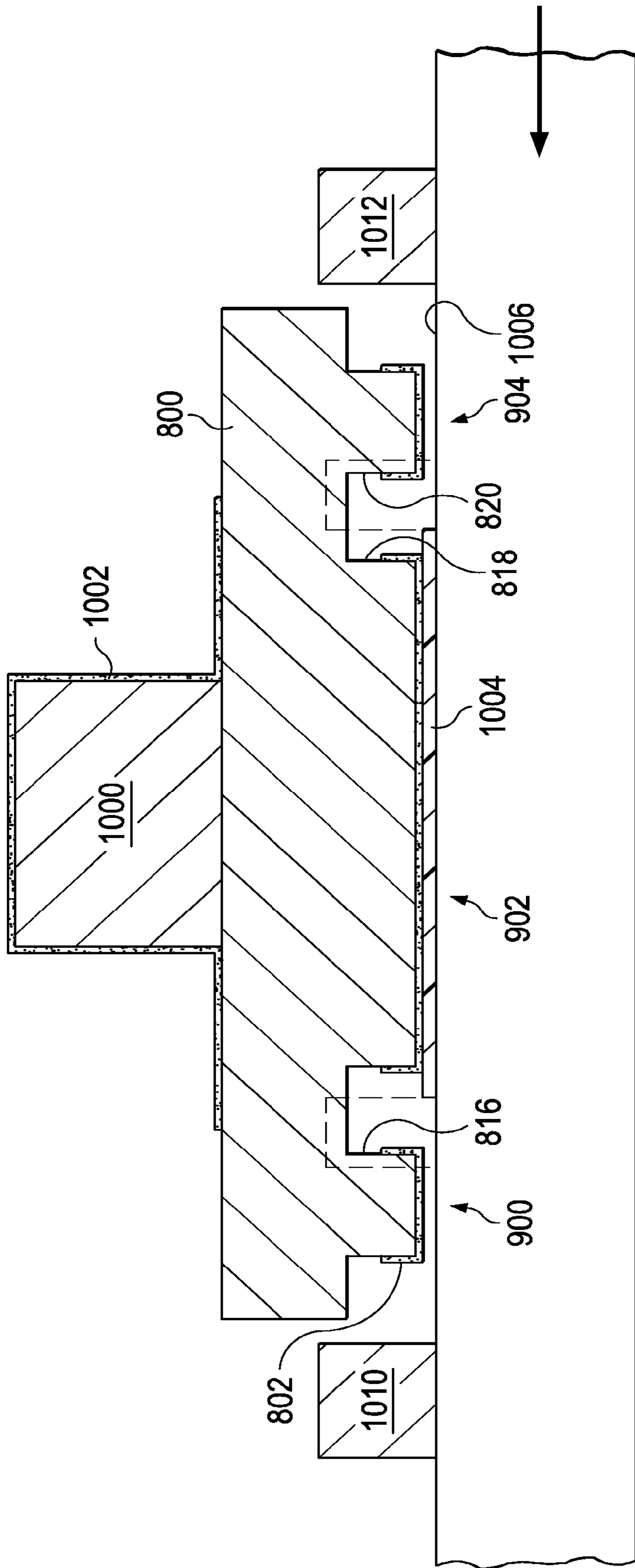


FIG. 10

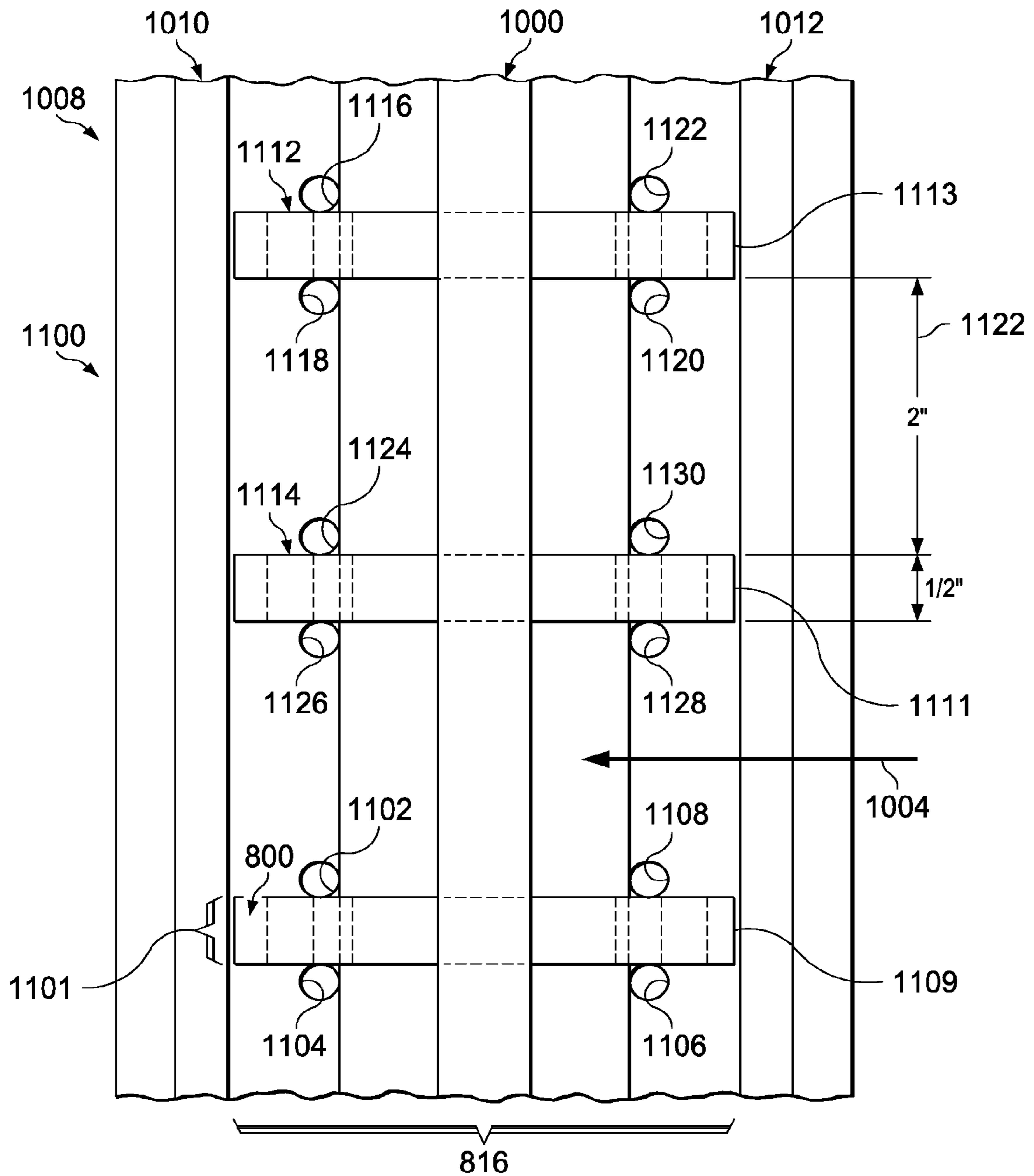
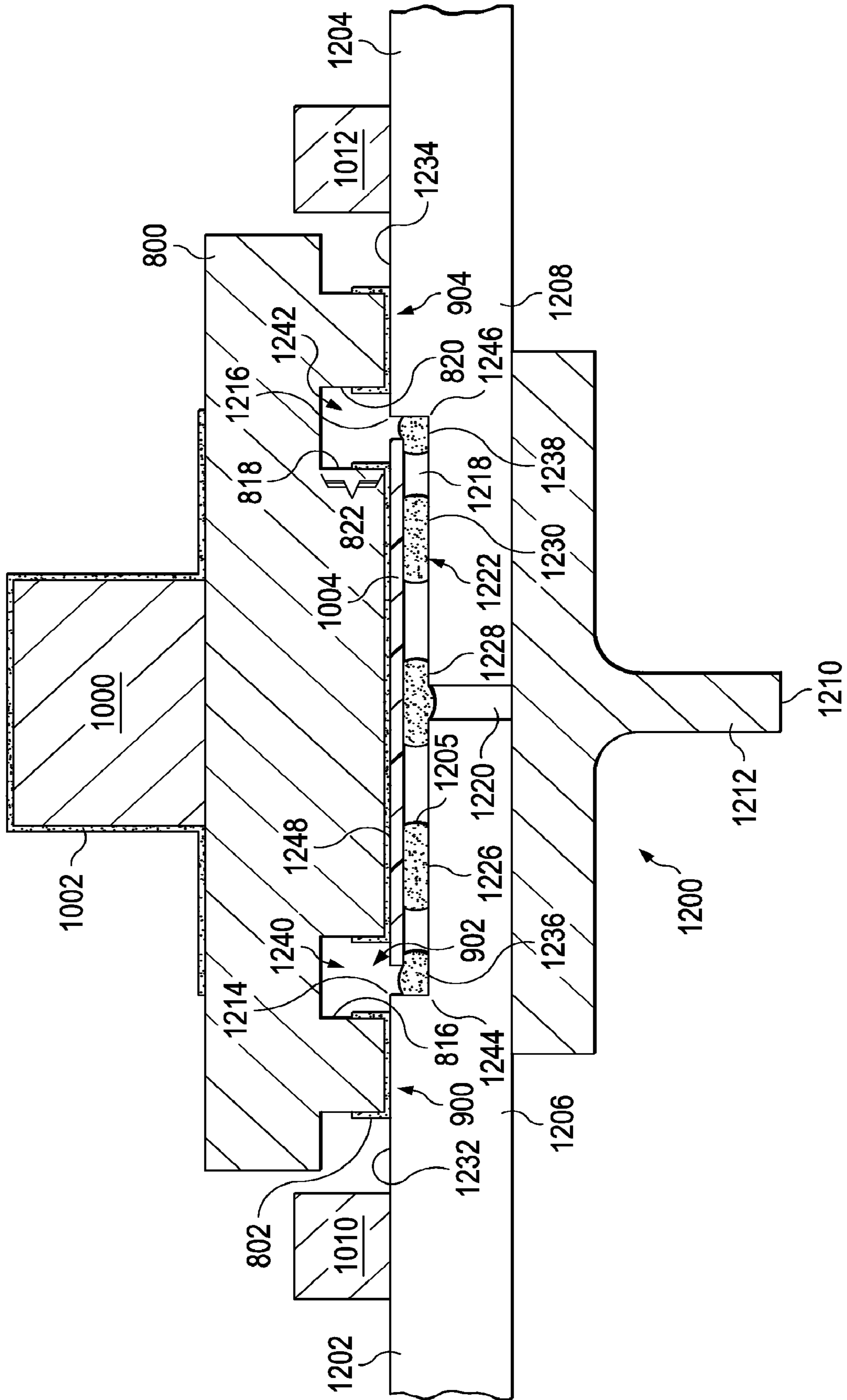


FIG. 11

FIG. 12



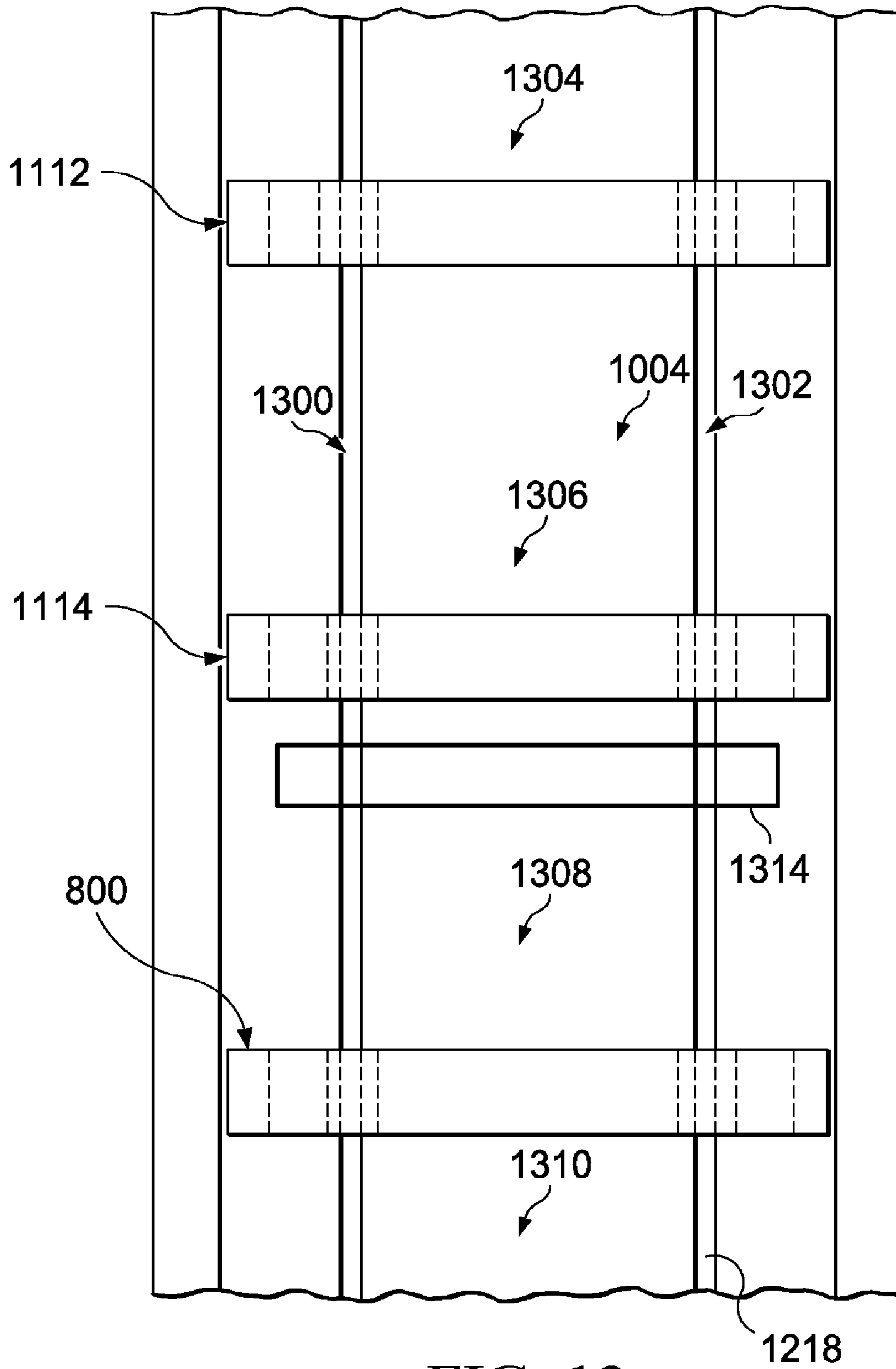


FIG. 13

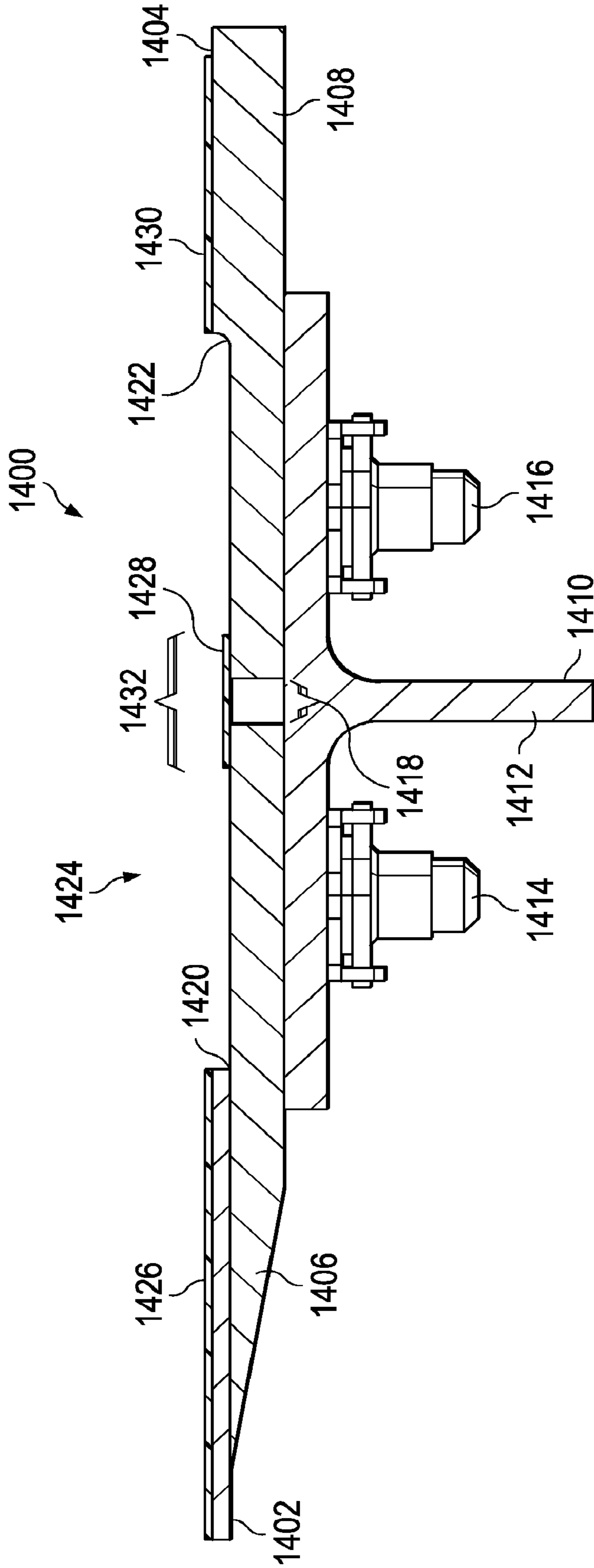


FIG. 14



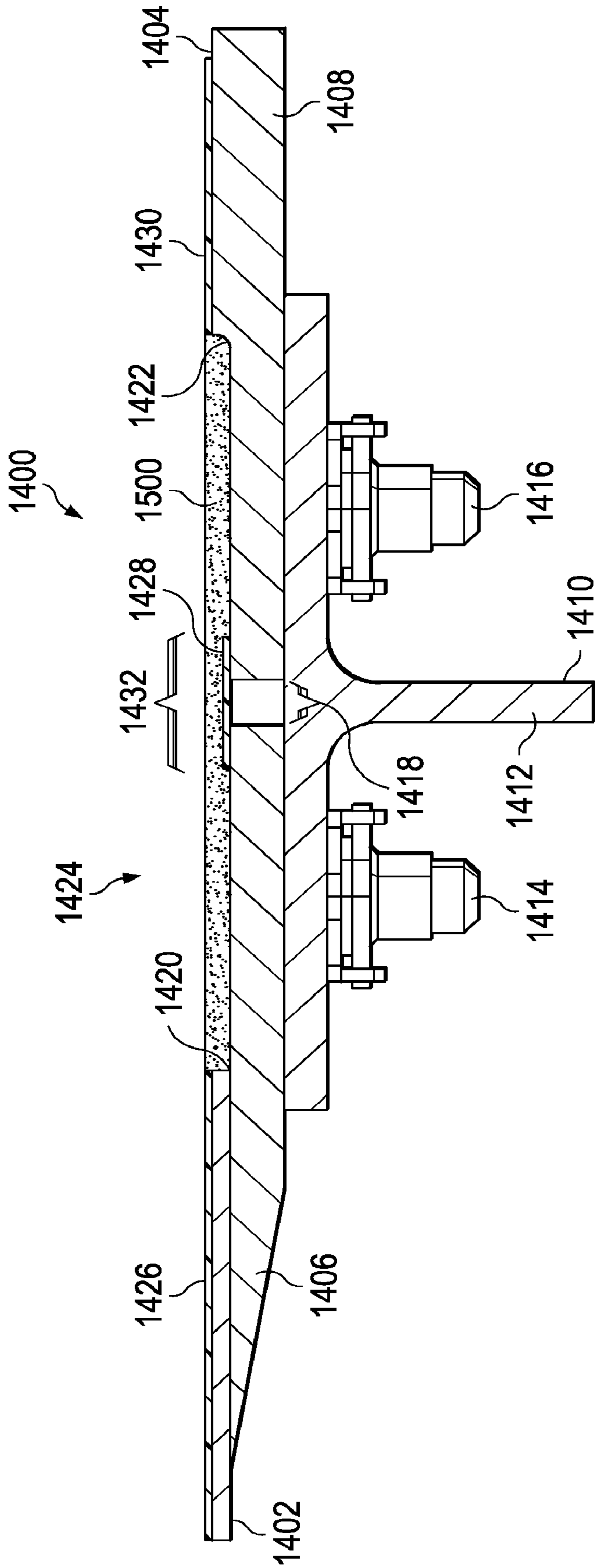


FIG. 15



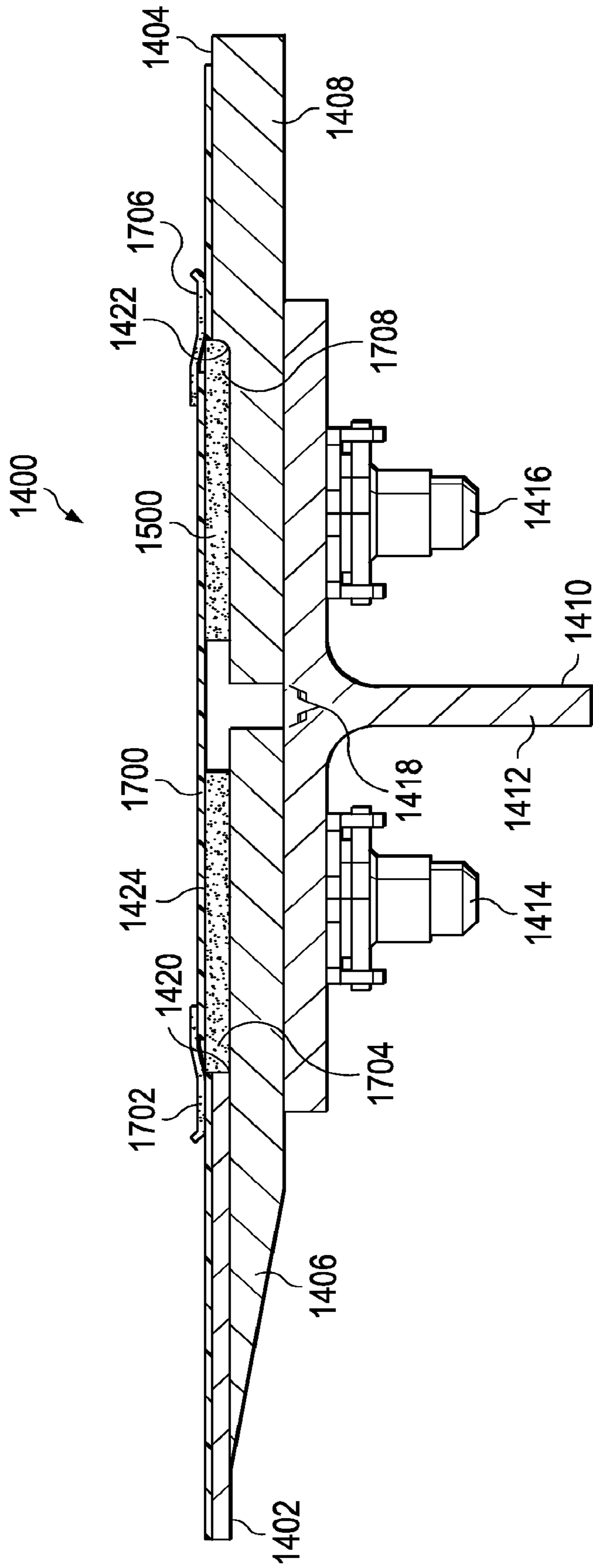


FIG. 17

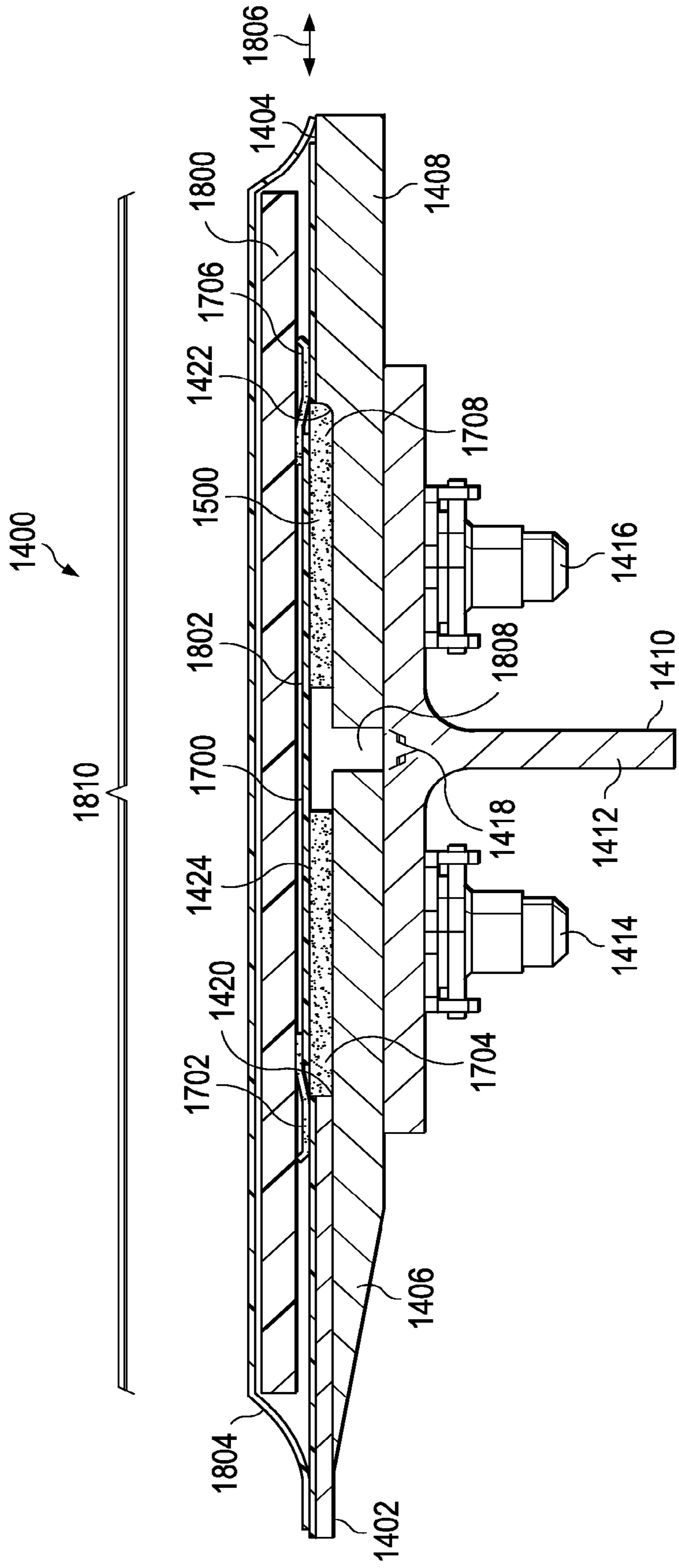


FIG. 18

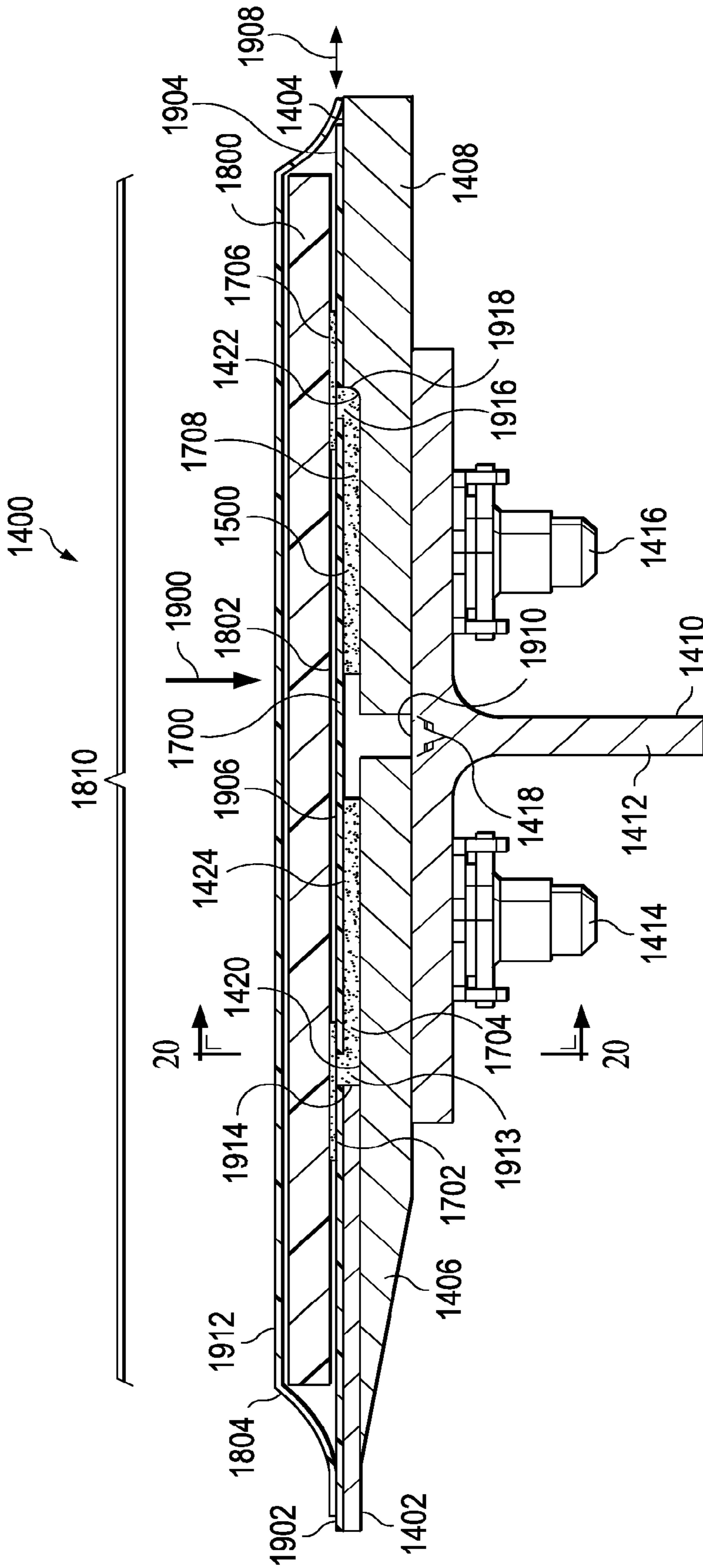


FIG. 19



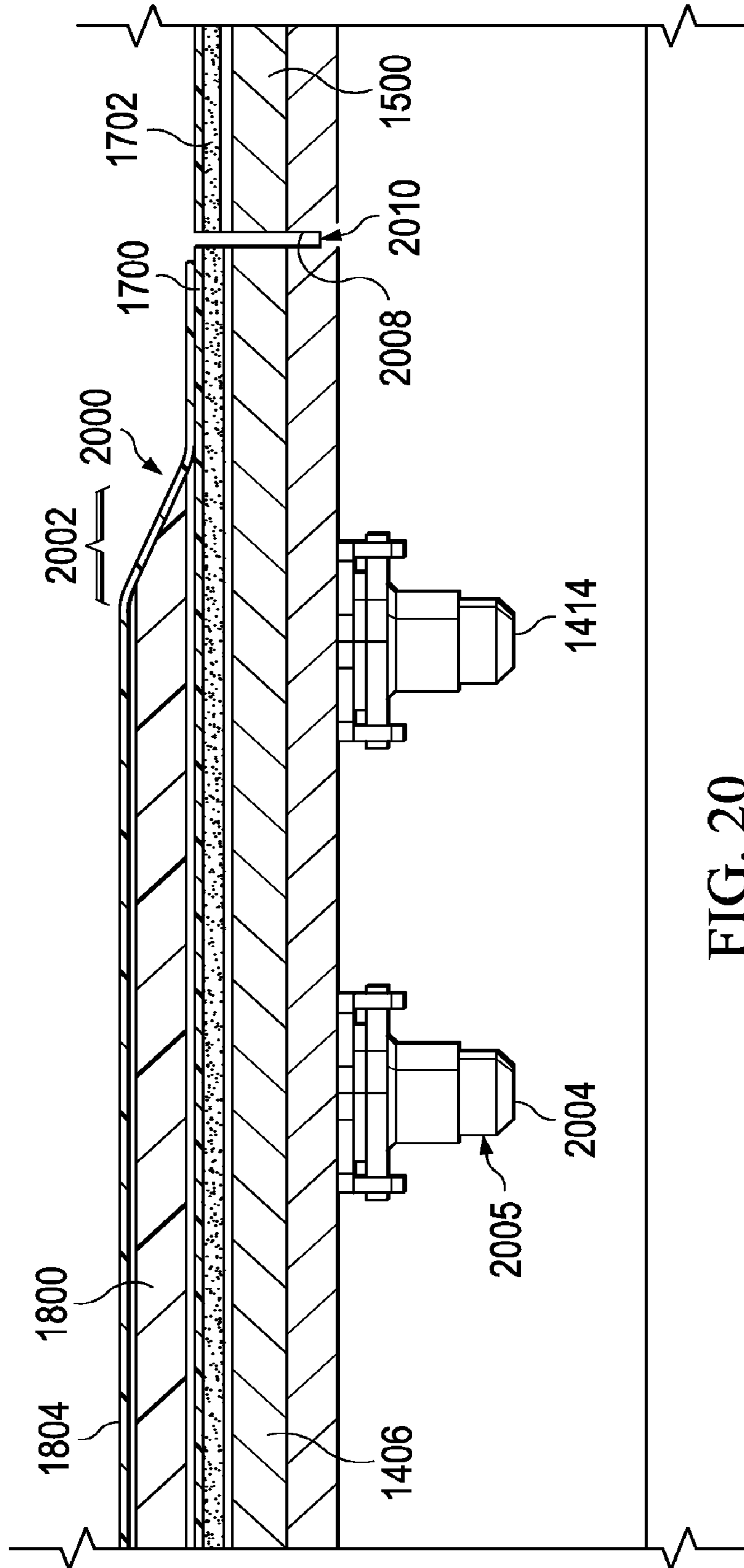


FIG. 20

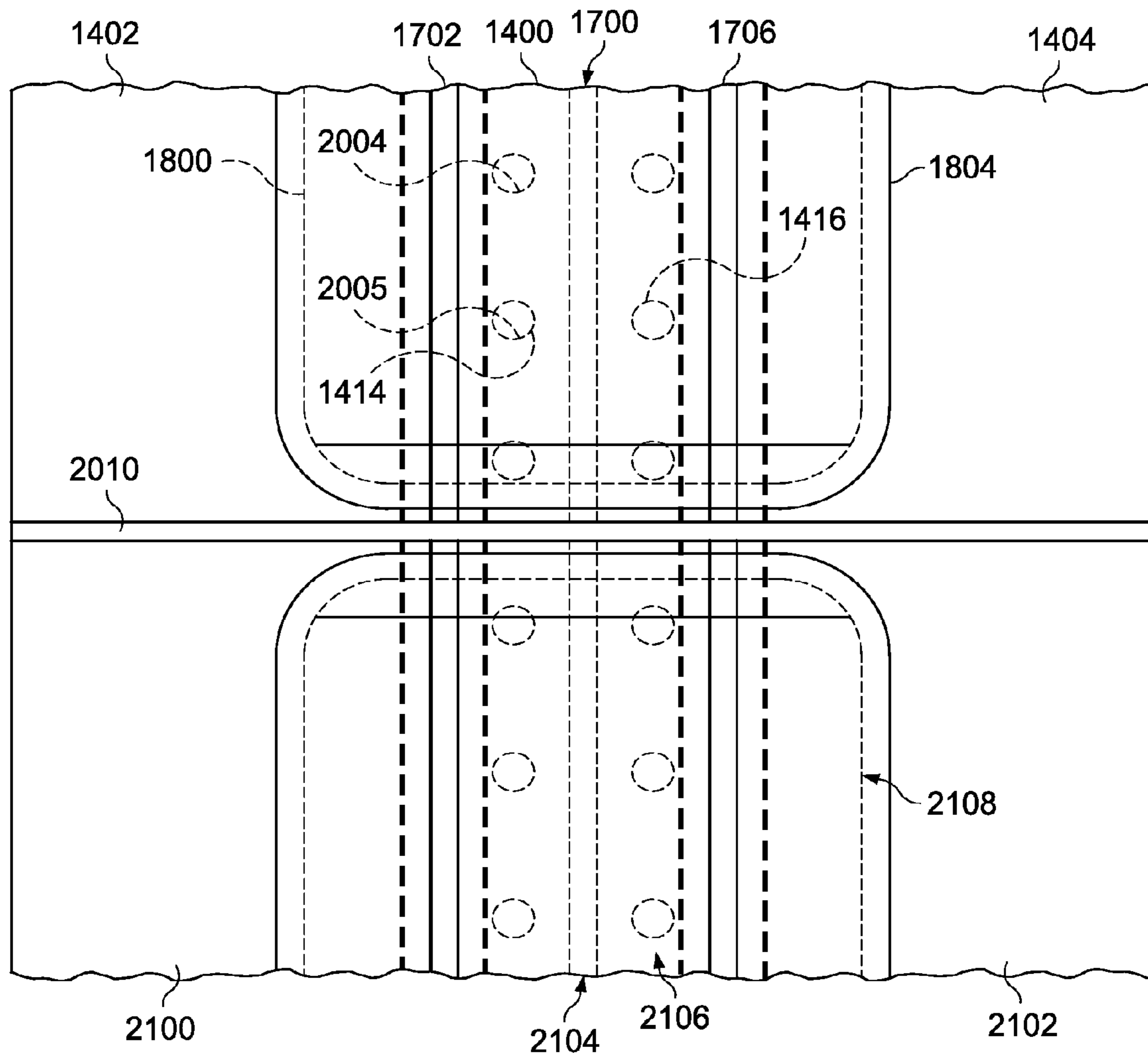


FIG. 21

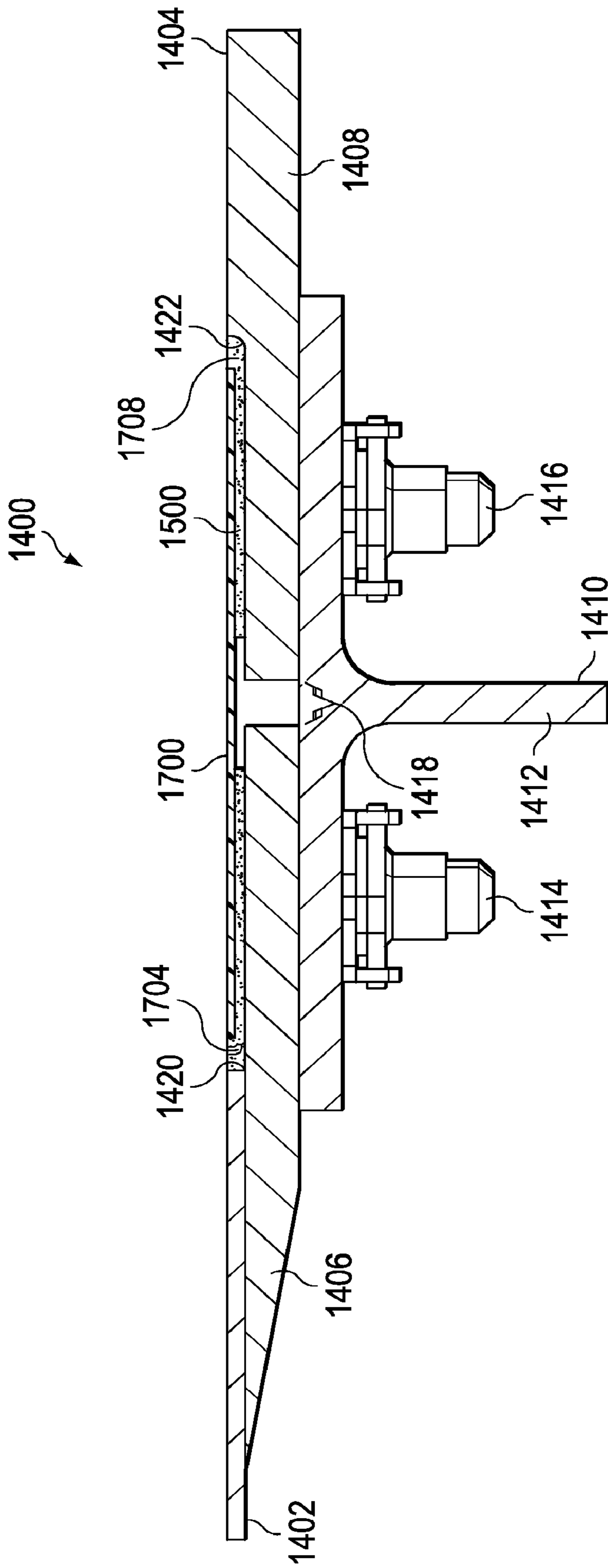


FIG. 22

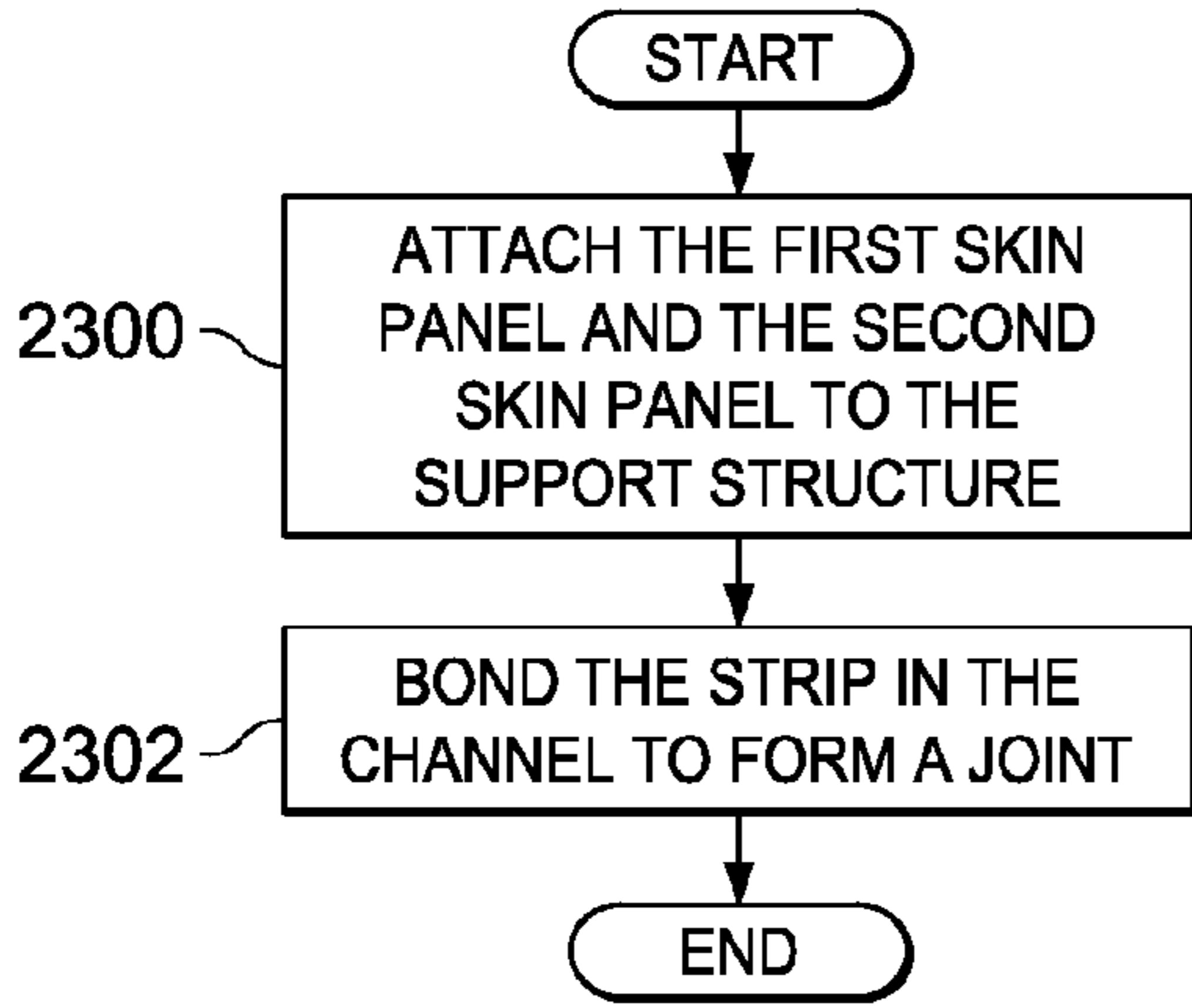


FIG. 23

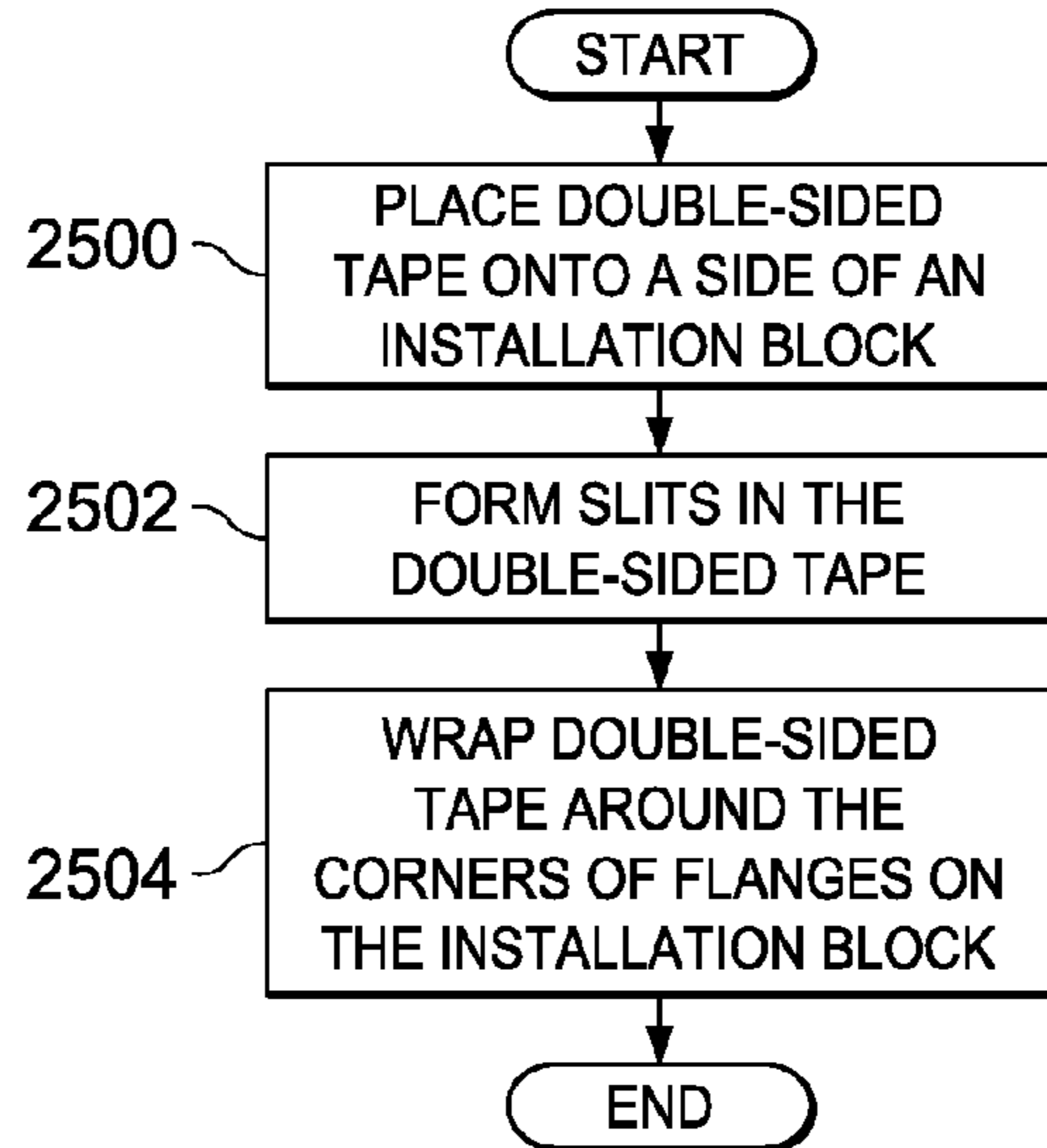


FIG. 25

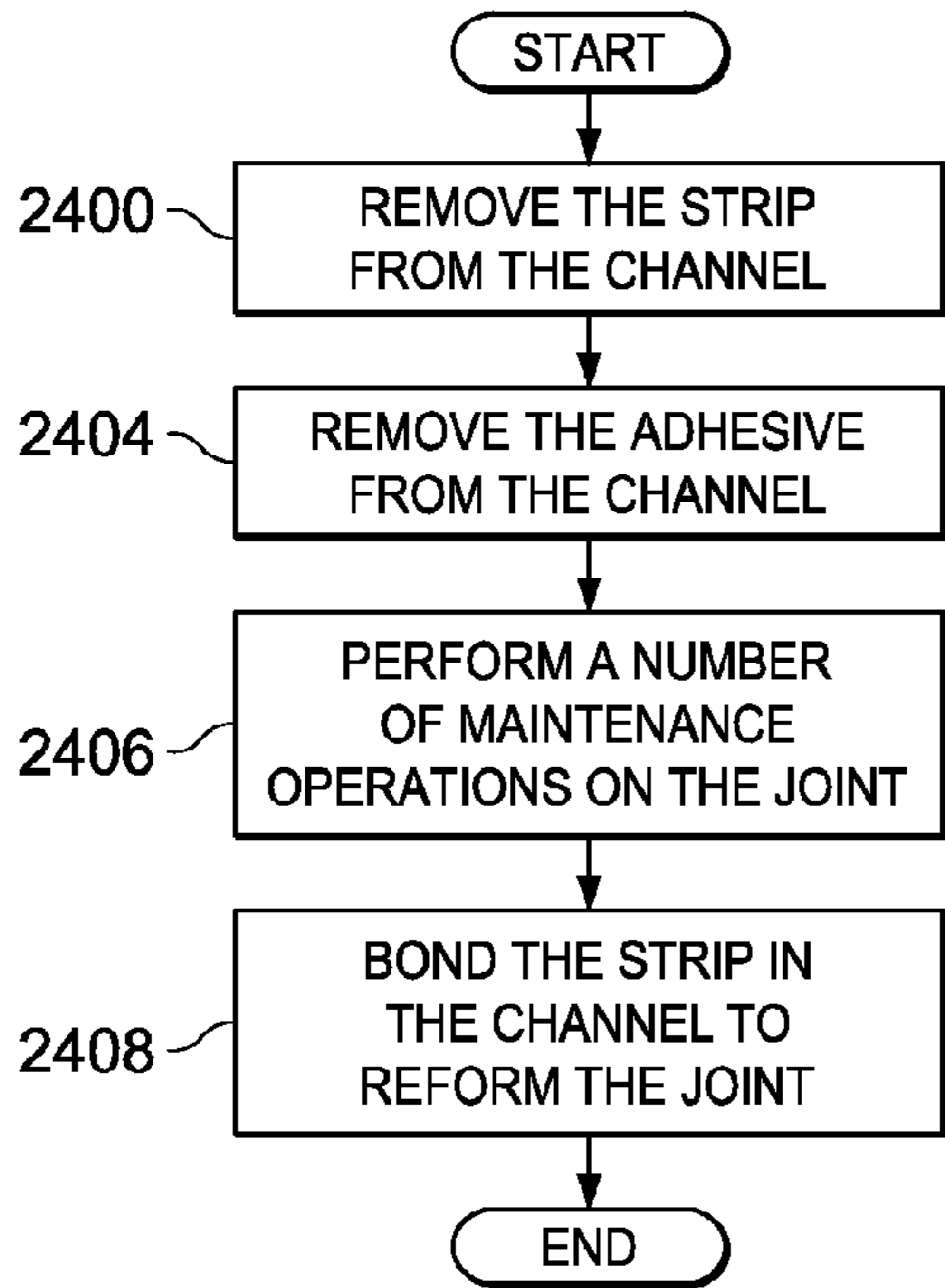


FIG. 24

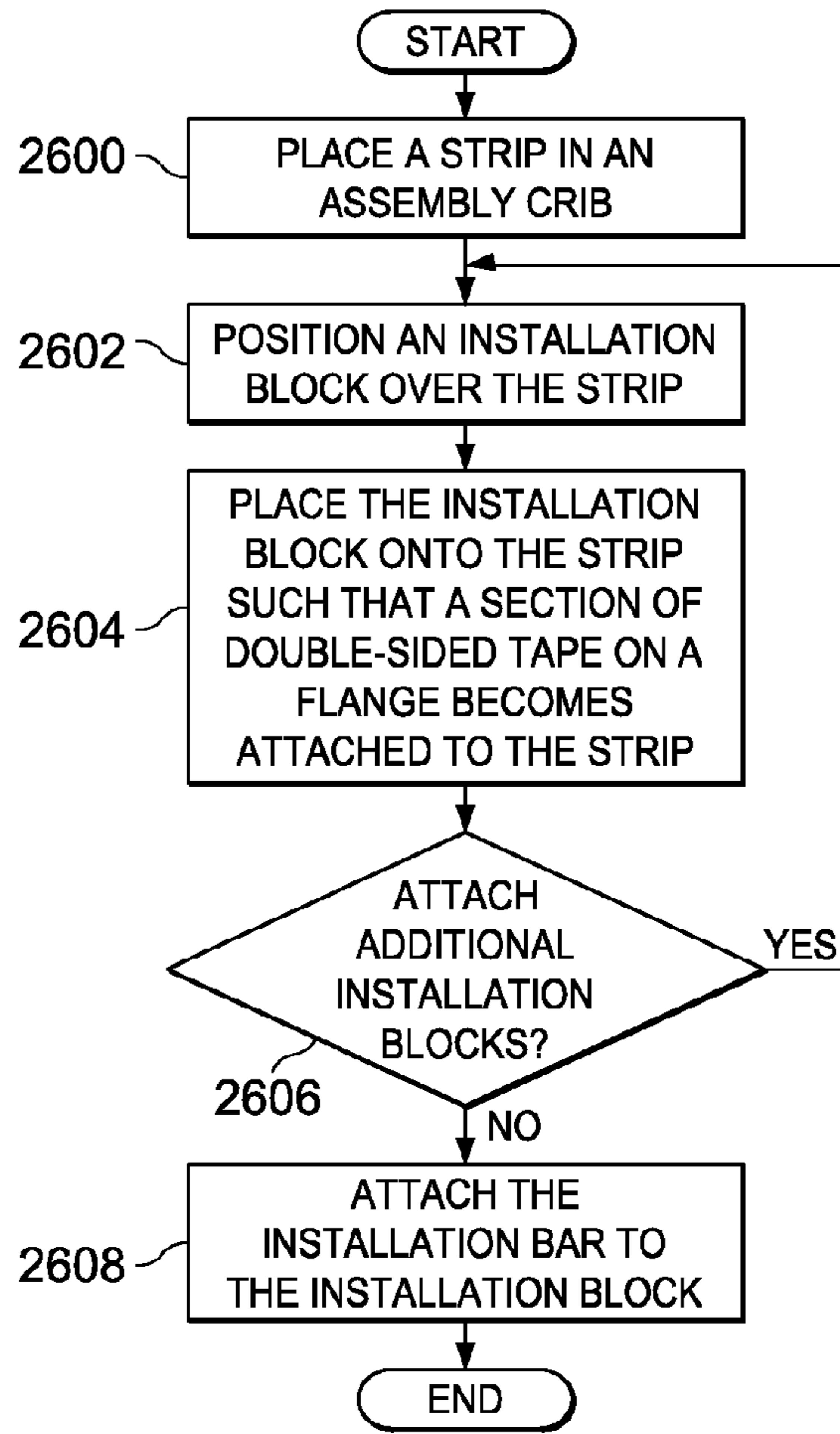


FIG. 26

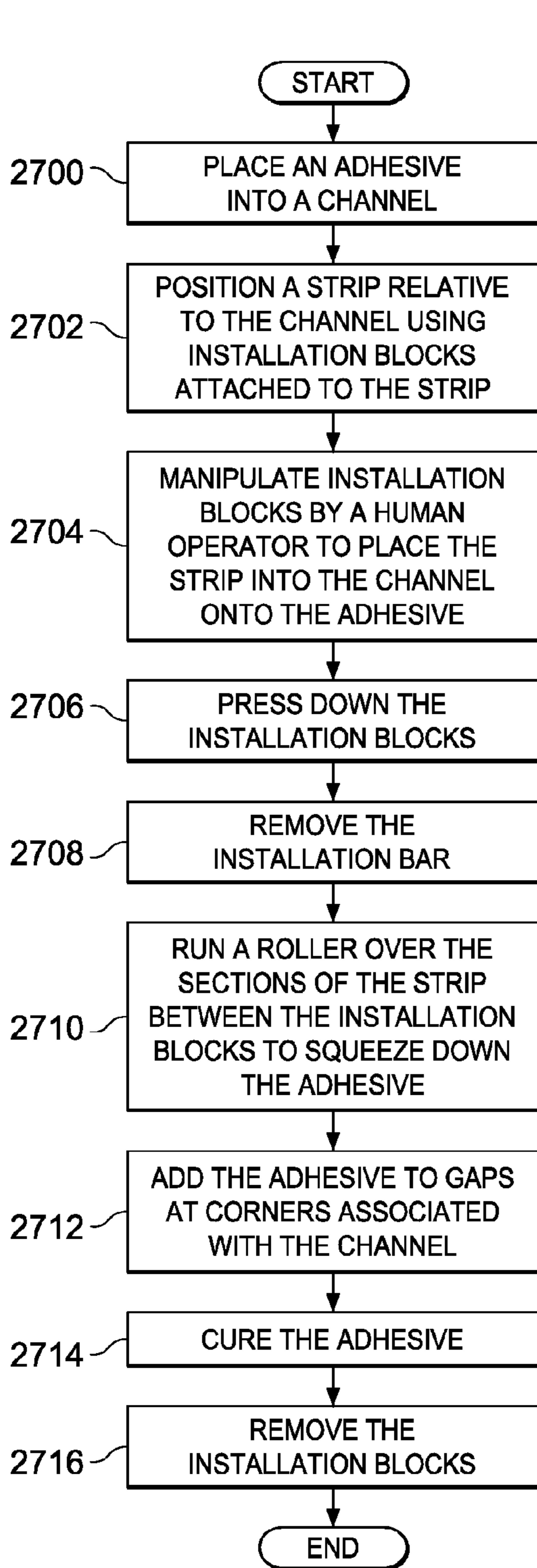


FIG. 27

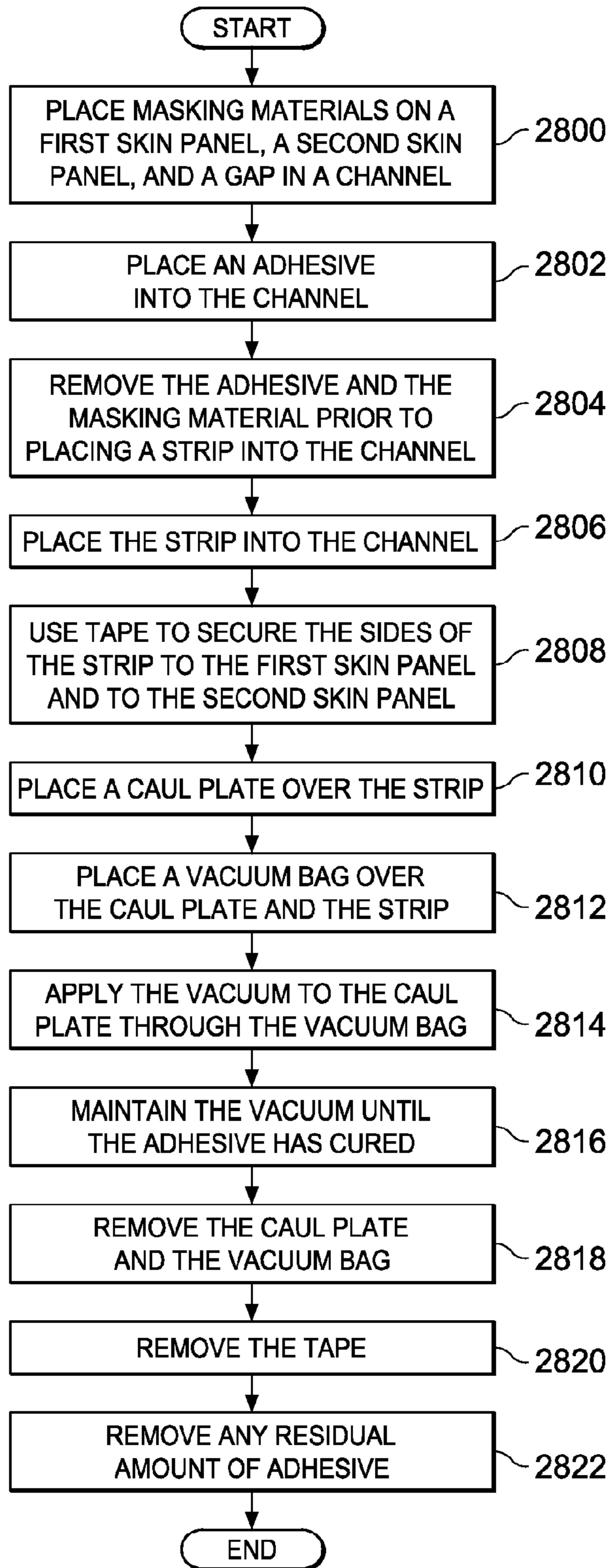


FIG. 28



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## SKIN PANEL JOINT FOR IMPROVED AIRFLOW

### CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a Divisional of and claims the benefit of priority to U.S. patent application Ser. No. 12/489,142, filed on Jun. 22, 2009 and entitled "Skin Panel Joint for Improved Airflow", status Pending, the contents of which are hereby incorporated by reference.

### BACKGROUND INFORMATION

#### 1. Field

The present disclosure relates generally to aircraft and, in particular, to a method and apparatus for an aircraft joint. Still more particularly, the present disclosure relates to a method and apparatus for an aircraft joint with improved airflow.

#### 2. Background

A fixed-wing aircraft may be a heavier-than-air vehicle capable of flying in the air. A fixed-wing aircraft may be capable of flying due to lift, which may be generated by the wings of the aircraft. Lift may be a component of an air dynamic force acting on the aircraft. This force may be perpendicular to an oncoming flow direction. During flight, an aircraft may also experience a drag force that may be in the direction of air flow.

The performance of an aircraft may be improved through the reduction of drag that may occur when air flows over the surface of an aircraft. Laminar flow may be used to reduce drag on an aircraft. Laminar flow occurs when air flows in parallel layers without mixing between the layers of air.

With an aircraft wing, air flowing over the wing may have a boundary layer. A boundary layer may be a very thin layer of air lying over the surface of the wing and other surfaces of the aircraft. This layer of air may tend to adhere to the aircraft wing. As the aircraft wing moves forward through the air, the boundary layer at first may flow smoothly with laminar flow over the wing.

Surface discontinuities may disrupt the laminar boundary layer of air over an aircraft wing and cause it to become turbulent. A turbulent boundary layer may be characterized by increased mixing between layers of air within the boundary layer. The drag caused by a turbulent boundary layer may be as much as around 5 to 10 times larger than the drag of a laminar boundary layer. This transition from laminar flow to turbulent flow within the boundary layer may increase drag. Also, this transition may produce undesirable noise, decrease fuel efficiency, and/or other undesirable effects during flight. These discontinuities may be caused by, for example, without limitation, steps and/or gaps in joints between skin panels on an aircraft.

Maintaining a laminar boundary layer past joints between skin panels on a painted aircraft may require changes in the surface that may have tight tolerances to avoid turbulent flow. For example, these changes may include tolerances for a step in the surface, a gap, waviness, and/or other discontinuities on the surface of the aircraft. A step may be a deviation from a plane across a skin panel joint on a surface. A step also may be an abrupt deviation from a desired smoothness for the surface.

For example, a tolerance for a step may be around 0.002 inches or less to maintain a laminar boundary layer past a joint. Gaps within this tolerance may be from around 0.020 inches to around 0.050 inches. This tolerance may be difficult to achieve at joints in which skin panels meet each other with currently used manufacturing and/or installation methods for

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skin panels for aircraft. Further, the removal and/or reinstallation of skin panels during maintenance also may provide challenges to meeting desired tolerances for maintaining laminar flow over the surface of an aircraft.

5 One solution involves filling a gap between skin panels with a filler such as, for example, without limitation, a hardened epoxy filler putty. With this type of solution, fastener heads may be recessed below the surface. These fastener heads may then be covered with an epoxy filler. The epoxy filler may then be sanded to obtain the desired smoothness with respect to the surface of the skin panels. Further, mismatches at low spots at which the skin panels are attached to the support structure also may be filled with an epoxy filler and sanded down.

15 This type of approach, however, may be labor intensive and increase the cost of manufacturing or maintaining an aircraft. Further, the durability of these types of fillers may require reapplication of the fillers more frequently than desired. As a result, an aircraft may be out of service for maintenance more often than desired.

20 Therefore, it would be advantageous to have a method and apparatus that takes into account one or more of the issues discussed above, as well as possibly other issues.

### SUMMARY

25 In one advantageous embodiment, an apparatus may comprise a first skin panel having a first surface, a second skin panel having a second surface, a first flange located at an end of the first skin panel, a second flange located at an end of the second skin panel, and a strip having a third surface. The first skin panel may be located adjacent to the second skin panel such that the first flange and the second flange form a channel. The strip may be bonded in the channel. Fluid flow over the third surface of the strip, the first surface of the first skin panel, and the second surface of the second skin panel may have a desired state.

30 In another advantageous embodiment, an aircraft joint may comprise a first skin panel having a first surface, a second skin panel having a second surface, a first flange located at an end of the first skin panel, a second flange located at an end of the second skin panel, a plurality of fasteners, a strip having a third surface, an adhesive, and a coating attached to at least a portion of the first surface of the first skin panel. The first skin panel and the second skin panel may be located on an aircraft and may be comprised of a material selected from one of aluminum, steel, titanium, and a composite material. The first skin panel may be located adjacent to the second skin panel such that the first flange and the second flange form a channel. The plurality of fasteners may attach the first flange and the second flange to a spar. The plurality of fasteners may have a plurality of heads having a non-stick coating, wherein the plurality of heads may be substantially coplanar to a surface of the first flange and a surface of the second flange through which the plurality of fasteners extend. The strip may be bonded in the channel. A first gap may be present between a first side of the strip and the end of the first skin panel, and a second gap may be present between a second side of the strip and the end of the second skin panel. The strip may be comprised of a material selected from one of aluminum, steel, titanium, and the composite material. The adhesive may bond the strip in the channel and may be configured to act as a sealant. The coating may extend into the channel. Airflow over the third surface of the strip, the first surface of the first skin panel, and the second surface of the second skin panel may have a substantially laminar airflow.



In yet another advantageous embodiment, a method may be present for forming a joint. A first skin panel and a second skin panel may be attached to a support structure. The first skin panel may have a first surface and a first flange located at an end of the first skin panel, and the second skin panel may have a second surface and a second flange located at an end of the second skin panel. The first flange and the second flange may be positioned to form a channel. A strip having a third surface may be bonded in the channel to form the joint, wherein a fluid flow over the first surface, the second surface, and the third surface may have a desired state.

In still yet another advantageous embodiment, a method may be present for forming a joint on an aircraft. A first skin panel and a second skin panel may be attached to a support structure. The first skin panel may have a first surface and a first flange located at an end of the first skin panel, and the second skin panel may have a second surface and a second flange located at an end of the second skin panel. The first flange and the second flange may be positioned to form a channel. The first skin panel and the second skin panel may be comprised of a material selected from one of aluminum, steel, titanium, and a composite material. A double-sided adhesive tape may be placed on a first side of a number of installation blocks. The number of installation blocks each may have a first flange, a second flange, and a third flange. A strip may be attached to the double-sided adhesive tape on the first side of the number of installation blocks. The strip may be comprised of a material selected from one of aluminum, steel, titanium, and a composite material. The strip may be attached to the double-sided adhesive tape on the first side of the number of installation blocks using an assembly crib with a plurality of guard rails and a plurality of pegs. An adhesive may be placed in the channel. The number of installation blocks may be attached to the first surface of the first skin panel and the second surface of the second skin panel over the channel to position the strip with the number of installation blocks in the channel to contact the adhesive in the channel such that a third surface of the strip may be in a desired position relative to the first surface of the first skin panel and the second surface of the second skin panel. The second flange of each installation block may attach to the strip. The first flange of each installation block may contact the first surface of the first skin panel, and the third flange of each installation block may contact the second surface of the second skin panel such that the third surface of the strip may be in the desired position. The adhesive may be cured to bond the strip in the channel to form the joint.

In a further advantageous embodiment, a method may be present for forming a joint on an aircraft. A first skin panel and a second skin panel may be attached to a spar. The first skin panel may have a first surface and a first flange located at an end of the first skin panel, the second skin panel may have a second surface and a second flange located at an end of the second skin panel, the first flange and the second flange may be positioned to form a channel, and the first skin panel and the second skin panel may be comprised of a material selected from one of aluminum, steel, titanium, and a composite material. A masking material may be placed on the first skin panel, on the second skin panel, and over a gap in the channel. An adhesive may be placed into the channel after placing the masking material on the first skin panel, on the second skin panel, and over the gap in the channel. The adhesive and the masking material over the gap may be removed in the channel prior to placing a strip on the adhesive. The strip may be placed on the adhesive on a surface of the channel. A caul plate may be placed over the strip. The caul plate placed over the strip may be covered with a vacuum bag prior to applying

a vacuum. The vacuum may be applied to the caul plate. The caul plate may push the strip downward into the channel such that a fluid flow over the first surface and the second surface has a desired state.

In another advantageous embodiment, a method may be present for performing maintenance operations on a joint. A strip may be removed from the joint in a channel in which the joint comprises the strip, a first skin panel, and a second skin panel to a support structure. The first skin panel may have a first surface and a first flange located at an end of the first skin panel, the second skin panel may have a second surface and a second flange located at an end of the second skin panel, and the first flange and the second flange may be positioned to form the channel. A number of maintenance operations may be performed after removing the strip. A replacement strip having a third surface may be bonded in the channel to form the joint. A fluid flow over the first surface, the second surface, and the third surface may have a desired state.

The features, functions, and advantages can be achieved independently in various embodiments of the present disclosure or may be combined in yet other embodiments in which further details can be seen with reference to the following description and drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

The novel features believed characteristic of the advantageous embodiments are set forth in the appended claims. The advantageous embodiments, however, as well as a preferred mode of use, further objectives, and advantages thereof, will best be understood by reference to the following detailed description of an advantageous embodiment of the present disclosure when read in conjunction with the accompanying drawings, wherein:

FIG. 1 is an illustration of an aircraft manufacturing and service method in accordance with an advantageous embodiment;

FIG. 2 is an illustration of an aircraft in which an advantageous embodiment may be implemented;

FIG. 3 is an illustration of a platform having surfaces with improved fluid flow in accordance with an advantageous embodiment;

FIG. 4 is an illustration of a portion of an aircraft in accordance with an advantageous embodiment;

FIG. 5 is an illustration of a cross-sectional view of a portion of a vertical stabilizer in accordance with an advantageous embodiment;

FIG. 6 is an illustration of a more-detailed view of a joint in a vertical stabilizer in accordance with an advantageous embodiment;

FIG. 7 is an illustration of an exploded perspective view of a joint in accordance with an advantageous embodiment;

FIG. 8 is an illustration of an installation block in accordance with an advantageous embodiment;

FIG. 9 is an illustration of double-sided tape installed on an installation block in accordance with an advantageous embodiment;

FIG. 10 is an illustration of an installation block attached to a strip in accordance with an advantageous embodiment;

FIG. 11 is an illustration of a top view of an assembly crib in accordance with an advantageous embodiment;

FIG. 12 is an illustration of a strip installed into a channel using an installation block in accordance with an advantageous embodiment;

FIG. 13 is an illustration of a top view of a strip installed in a joint in accordance with an advantageous embodiment;



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FIG. 14 is an illustration of a joint in which a strip may be installed in accordance with an advantageous embodiment;

FIG. 15 is an illustration of a channel filled with sealant in accordance with an advantageous embodiment;

FIG. 16 is an illustration of sealant removed from portions of a joint in accordance with an advantageous embodiment;

FIG. 17 is an illustration of a strip placed into a channel of a joint in accordance with an advantageous embodiment;

FIG. 18 is an illustration of a caul plate in a vacuum bag placed over a joint in accordance with an advantageous embodiment;

FIG. 19 is an illustration of a vacuum applied to a vacuum bag and caul plate in accordance with an advantageous embodiment;

FIG. 20 is an illustration of a vacuum applied to a vacuum bag and a caul plate in accordance with an advantageous embodiment;

FIG. 21 is an illustration of a top view of a joint formed by using a strip, a caul plate, and a vacuum bag in accordance with an advantageous embodiment;

FIG. 22 is an illustration of a completed joint in accordance with an advantageous embodiment;

FIG. 23 is an illustration of a flowchart for forming a joint in accordance with an advantageous embodiment;

FIG. 24 is an illustration of a flowchart for performing maintenance on a joint in accordance with an advantageous embodiment;

FIG. 25 is an illustration of a process for preparing a strip for bonding in a channel in accordance with an advantageous embodiment;

FIG. 26 is an illustration of a flowchart for attaching a strip to an installation block in accordance with an advantageous embodiment;

FIG. 27 is an illustration of a flowchart of a process for positioning a strip in a channel for bonding in accordance with an advantageous embodiment; and

FIG. 28 is an illustration of a flowchart of a process for bonding a strip in a channel in accordance with an advantageous embodiment.

## DETAILED DESCRIPTION

Referring more particularly to the drawings, embodiments of the disclosure may be described in the context of aircraft manufacturing and service method 100 as shown in FIG. 1 and aircraft 200 as shown in FIG. 2. Turning first to FIG. 1, an illustration of an aircraft manufacturing and service method is depicted in accordance with an advantageous embodiment. During pre-production, aircraft manufacturing and service method 100 may include specification and design 102 of aircraft 200 in FIG. 2 and material procurement 104.

During production, component and subassembly manufacturing 106 and system integration 108 of aircraft 200 in FIG. 2 takes place. Thereafter, aircraft 200 in FIG. 2 may go through certification and delivery 110 in order to be placed in service 112. While in service by a customer, aircraft 200 in FIG. 2 is scheduled for routine maintenance and service 114, which may include modification, reconfiguration, refurbishment, and other maintenance or service.

Each of the processes of aircraft manufacturing and service method 100 may be performed or carried out by a system integrator, a third party, and/or an operator. In these examples, the operator may be a customer. For the purposes of this description, a system integrator may include, without limitation, any number of aircraft manufacturers and major-system subcontractors; a third party may include, without limitation, any number of vendors, subcontractors, and suppliers; and an

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operator may be an airline, leasing company, military entity, service organization, and so on.

With reference now to FIG. 2, an illustration of an aircraft is depicted in which an advantageous embodiment may be implemented. In this example, aircraft 200 is produced by aircraft manufacturing and service method 100 in FIG. 1 and may include airframe 202 with a plurality of systems 204 and interior 206. Examples of systems 204 include one or more of propulsion system 208, electrical system 210, hydraulic system 212, and environmental system 214. Any number of other systems may be included. Although an aerospace example is shown, different advantageous embodiments may be applied to other industries, such as the automotive industry.

Apparatus and methods embodied herein may be employed during at least one of the stages of aircraft manufacturing and service method 100 in FIG. 1. As used herein, the phrase “at least one of”, when used with a list of items, means that different combinations of one or more of the listed items may be used and only one of each item in the list may be needed. For example, “at least one of item A, item B, and item C” may include, for example, without limitation, item A or item A and item B. This example also may include item A, item B, and item C or item B and item C.

As one illustrative example, components or subassemblies produced in component and subassembly manufacturing 106 in FIG. 1 may be fabricated or manufactured in a manner similar to components or subassemblies produced while aircraft 200 is in service 112 in FIG. 1. As yet another example, number of apparatus embodiments, method embodiments, or a combination thereof may be utilized during production stages, such as component and subassembly manufacturing 106 and system integration 108 in FIG. 1.

A number, when referring to items, means one or more items. For example, a number of apparatus embodiments is one or more apparatus embodiments. A number of apparatus embodiments, method embodiments, or a combination thereof may be utilized while aircraft 200 is in service 112 and/or during maintenance and service 114 in FIG. 1. The use of a number of the different advantageous embodiments may substantially expedite the assembly of or reduce the cost of aircraft 200.

One or more of the advantageous embodiments may include an apparatus having a first skin panel having a first surface, a second skin panel having a second surface, a first flange located at the end of the first skin panel, a second flange located at the end of the second skin panel, and a strip having a surface. The first skin panel may be located adjacent to the second skin panel such that the first flange and the second flange form a channel. This channel may be part of a joint. The strip may be bonded in the channel. The fluid flow over the surface of the strip, the surface of the first skin panel, and the surface of the second skin panel may have a desired level. For example, the surface of the strip may be flush with the surfaces of the adjacent skin panels such that laminar flow may occur.

With reference now to FIG. 3, an illustration of a platform having surfaces with improved fluid flow is depicted in accordance with an advantageous embodiment. In this advantageous embodiment, platform 300 may take the form of aircraft 302. Aircraft 302 may be, for example, without limitation, aircraft 200 in FIG. 2. In this illustrative example, aircraft 302 may have surface 304 over which fluid flow 306 may occur. Fluid flow 306 may be movement of fluid 307 over surface 304. For example, fluid flow 306 may take the form of airflow 308 in these depicted examples. Airflow 308 may take the form of laminar airflow 310.



In these depicted examples, surface **304** may comprise plurality of skin panels **312**. For example, without limitation, plurality of skin panels **312** may include first skin panel **314** and second skin panel **316**. First skin panel **314** may have first surface **318**, and second skin panel **316** may have second surface **320**. Additionally, first flange **322** may be associated with first skin panel **314** at end **324** of first skin panel **314**. Second flange **326** may be associated with second skin panel **316** at end **328** of second skin panel **316**.

A first component may be considered to be associated with a second component by being secured to the second component, bonded to the second component, fastened to the second component, and/or connected to the second component in some other suitable manner. The first component also may be considered to be associated with the second component by being formed as part of and/or an extension of the second component.

First flange **322** may have step **330**, while second flange **326** may have step **332**. In these illustrative examples, step **330** and step **332** may be below first surface **318** and second surface **320**, respectively. In these illustrative examples, end **324** of first skin panel **314** may be located adjacent to end **328** of second skin panel **316** to form joint **334**. End **324** and end **328** may be arranged such that first flange **322** and second flange **326** form channel **336**.

Plurality of skin panels **312** may take various forms. For example, without limitation, plurality of skin panels **312** may be comprised of materials selected from at least one of aluminum, steel, titanium, a composite material, and/or any other suitable material.

In these illustrative examples, first flange **322** and second flange **326** may be made of the same material as first skin panel **314** and second skin panel **316** or from a different material, depending on the particular implementation.

In these illustrative examples, first skin panel **314** and second skin panel **316** may be attached to support structure **338**. Support structure **338**, in this example, may be spar **340**. Of course, support structure **338** may take other forms, such as a frame, a stringer, a clip, a rib, or any other flanged structure.

In particular, first flange **322** for first skin panel **314** and second flange **326** for second skin panel **316** may be attached to support structure **338**. In these illustrative examples, plurality of fasteners **342** may attach first flange **322** and second flange **326** to support structure **338** to form joint **334**.

Strip **344** may be bonded in channel **336** for joint **334**. In these illustrative examples, strip **344** may take various forms. For example, without limitation, strip **344** may be comprised of plastic, a composite material, titanium, aluminum, or some other suitable material. Strip **344** may be bonded in channel **336** using adhesive **346**. Adhesive **346** may be any compound in a liquid and/or semi-liquid state that may be used to bond strip **344** in channel **336**.

In particular, adhesive **346** may be placed onto surface **348** of first flange **322** and surface **350** of second flange **326** in channel **336**. Then strip **344** may be placed into channel **336**. In other advantageous embodiments, adhesive **346** may be applied to strip **344** and/or surface **348** of first flange **322** and surface **350** of second flange **326** prior to the joining of first flange **322** and second flange **326** to form channel **336**. Strip **344** with adhesive **346** may then be placed onto surface **348** and surface **350**.

In these illustrative examples, adhesive **346** also may act as sealant **352**. In other words, adhesive **346** may be selected as a material that may prevent and/or reduce the penetration of undesirable components such as, for example, without limitation, air, gas, water, dust, and/or other undesirable compo-

nents. Further, adhesive **346** may be selected as a material that may elongate and/or remain flexible during use. The selection of adhesive **346** may be such that cracking may be reduced and/or avoided during use.

In these depicted examples, plurality of fasteners **342** may have non-stick coating **354** on heads **356** of plurality of fasteners **342**. Non-stick coating **354** may allow for easier removal of plurality of fasteners **342** during maintenance operations. For example, without limitation, non-stick coating **354** may prevent and/or reduce sticking of adhesive **346** to heads **356** of plurality of fasteners **342**. Further, plurality of fasteners **342** may be countersunk into surface **348** of first flange **322** and surface **350** of second flange **326**.

Strip **344** may be selected using a material having a similar thermal coefficient of expansion as first skin panel **314** and second skin panel **316**. Also, strip **344** may be selected using a material that provides flexibility or flexing of strip **344** during use.

At least one of first skin panel **314** and second skin panel **316** may have coating **358**. Coating **358** may be, for example, without limitation, paint **360**, appliqué **362**, and/or some other suitable type of coating. When coating **358** is applied to first surface **318** of first skin panel **314**, coating **358** may extend over edge **364** of first skin panel **314** at end **324** into channel **336**. Coating **358** may extend only into a portion of channel **336** rather than all of channel **336**.

Strip **344** may be selected to have thickness **366** and length **368**. These parameters and/or other parameters of strip **344** may be selected to provide a desired level of fluid flow **306** over first skin panel **314** and second skin panel **316**. In these examples, these parameters may be selected such that first surface **318** of first skin panel **314**, second surface **320** of second skin panel **316**, and third surface **378** of strip **344** have desired state **345** of fluid flow **306**. More specifically, these parameters may be selected such that boundary layer **347** of fluid flow **306** may have desired state **345**.

Desired state **345** of fluid flow **306** may be at least one of fluid flow **306** over joint **334**, over all of first surface **318** of first skin panel **314**, second surface **320** of second skin panel **316**, and third surface **378** of strip **344** on joint **334**, a portion of either or both first surface **318** of first skin panel **314**, second surface **320** of second skin panel **316**, and third surface **378** of strip **344** over joint **334**, or some other combination of components including joint **334**.

In these illustrative examples, desired state **345** for boundary layer **347** may be substantially laminar airflow **310**. Laminar airflow **310** may be distinguished from turbulent airflow **349** for boundary layer **347** by detecting velocity fluctuations **343** within boundary layer **347**, in these examples. For example, without limitation, velocity fluctuations **343** may be detected through the use of a laser anemometer.

The illustration of platform **300** in FIG. **3** is not meant to imply physical or architectural limitations to the manner in which different advantageous embodiments may be implemented. Other components in addition to and/or in place of the ones illustrated may be used. Some components may be unnecessary in some advantageous embodiments. Also, the blocks are presented to illustrate some functional components. One or more of these blocks may be combined and/or divided into different blocks when implemented in different advantageous embodiments.

For example, in some advantageous embodiments, platform **300** may take other forms. For example, platform **300** may be a submarine, and fluid flow **306** may be the flow of water. In yet other advantageous embodiments, only some of plurality of skin panels **312** may include a joint with a configuration such as joint **334** as described above.



With reference now to FIG. 4, an illustration of a portion of an aircraft is depicted in accordance with an advantageous embodiment. In this illustrative example, tail 400 of aircraft 402 is depicted. Aircraft 402 may be an example of one implementation of aircraft 302 in FIG. 3. In this example, the different advantageous embodiments may be applied to joint 404 near leading edge 405 of vertical stabilizer 406. The different advantageous embodiments also may be applied to other joints such as, for example, without limitation, joints 408 and 412 on horizontal stabilizers 410 and 414, respectively. These joints may be implemented using joint 334 in FIG. 3.

With reference next to FIG. 5, an illustration of a cross-sectional view of a portion of a vertical stabilizer is depicted in accordance with an advantageous embodiment. Joint 500 may be an example of one physical implementation for joint 334 in FIG. 3.

In this depicted example, vertical stabilizer 406 may be illustrated in a cross section taken along lines 5-5 in FIG. 4. In this example, joints 404 and 500 may be seen for vertical stabilizer 406. As can be seen in this example, joint 500 may be formed where skin panel 502 and skin panel 504 meet. Section 506 is shown in more detail below in FIG. 6.

With reference now to FIG. 6, an illustration of a more-detailed view of a joint in a vertical stabilizer is depicted in accordance with an advantageous embodiment. In this depicted example, flange 600 may be located at end 602 of skin panel 502. Flange 604 may be located at end 606 of skin panel 504.

In this illustrative example, flange 600 and flange 604 may be attached to support structure 608. In this illustrative example, support structure 608 may take the form of spar 610. Flange 600 may be attached to support structure 608 by fastener 612, and flange 604 may be secured to support structure 608 by fastener 614. As can be seen, step 616 may be present in flange 600, and step 618 may be present in flange 604. Additionally, gap 620 may be present between flange 600 and flange 604. In these illustrative examples, flanges 600 and 604 may be bonded to skin panels 502 and 504, respectively.

As can be seen in FIG. 6, flange 600 and flange 604 may form channel 622. Strip 624 may be bonded in channel 622. Gap 626 and gap 628 may still be present. Each of these gaps may have a width of around 0.020 inches to around 0.050 inches in these particular examples. Of course, other tolerances may be used, depending on the particular implementation. For example, the size of these gaps may be selected as being small enough to avoid undesirable airflow over surface 627 of skin panel 502, surface 629 of strip 624, and surface 630 of skin panel 504.

In these depicted examples, surface 627 of skin panel 502, surface 629 of strip 624, and surface 630 of skin panel 504 may lie substantially along plane 631 as indicated by line 633. In other words, strip 624 may be positioned relative to skin panel 502 and skin panel 504 such that these surfaces may provide airflow having a desired state. The desired state, in these examples, may be laminar airflow.

In this illustrative example, channel 622 may have length 632 and depth 634. Length 632 may be, for example, without limitation, around 1.80 inches. Depth 634 may be, for example, without limitation, around 0.04 inches. As can be seen, strip 624 may cover fasteners 612 and 614. Further, the dimensions of strip 624 may be selected to accommodate variations in skin panel 502 and/or skin panel 504. Additionally, strip 624 also may be selected to accommodate thicknesses for coatings that may be placed onto surface 627 and surface 630 of skin panel 502 and skin panel 504.

Turning now to FIG. 7, an illustration of an exploded perspective view of a joint is depicted in accordance with an advantageous embodiment. As can be seen in this illustrative example, head 700 for fastener 612 and head 702 for fastener 614 may be seen. Head 700 and head 702 may be countersunk into surface 704 of flange 600 and surface 706 of flange 604. In this illustrative example, head 700 and head 702 may be at a level substantially flush with surface 704. In other examples, head 700 and head 702 may be at a level below surface 704. Additionally, head 700 and head 702 may have a non-stick coating, which may allow for easier maintenance if strip 624 is removed from joint 500.

Turning now to FIGS. 8-13, illustrations of installation of a strip into a channel in a joint are depicted in accordance with an advantageous embodiment. These different figures may illustrate an illustrative example of one manner in which a strip, such as strip 344, may be installed to complete a joint, such as joint 334 in FIG. 3. This installation may occur during, for example, without limitation, at least one of manufacturing of joint 334 and maintenance of joint 334.

With reference to FIG. 8, an illustration of an installation block is depicted in accordance with an advantageous embodiment. In this illustrative example, installation block 800 may have double-sided tape 802 applied to side 804 of installation block 800. Double-sided tape 802 may have protective cover 806 on side 808. Slits 810 and 812 may be cut into double-sided tape 802 in these examples.

As depicted, installation block 800 may have height 814 and length 815. Height 814 may be around 1 inch, and length 815 may be around 4 inches in these illustrative examples. Additionally, installation block 800 also may have flange 816, flange 818, and flange 820. Each of these flanges may have height 822. Height 822 may be around 0.5 inches in these examples. Flange 816 may have length 824, flange 818 may have length 826, and flange 820 may have length 828. Lengths 824 and 828 may be around 0.5 inches, and length 826 may be around 1.7 inches. In these examples, installation block 800 may be comprised of a material such as, for example, without limitation, aluminum and/or some other suitable material.

With reference now to FIG. 9, an illustration of double-sided tape installed on an installation block is depicted in accordance with an advantageous embodiment. In this illustrative example, after slits 810 and 812 have been formed as depicted in FIG. 8, sections 900, 902, and 904 may be present for double-sided tape 802. Section 900 may be wrapped around corners 906 and 908 for flange 816. Section 902 may be wrapped around corners 910 and 912 of flange 818. Section 904 may be wrapped around corners 914 and 916 for flange 820.

With reference next to FIG. 10, an illustration of an installation block attached to a strip in an assembly crib is depicted in accordance with an advantageous embodiment. In this illustrative example, a side view of installation block 800 is shown. In this example, installation bar 1000 may be associated with installation block 800. In this illustrative example, installation bar 1000 may be associated with installation block 800 by attaching installation bar 1000 to installation block 800 with tape 1002. Of course, installation bar 1000 may be associated with installation block 800 in other ways. For example, without limitation, installation bar 1000 may be attached to installation block 800 by temporary fasteners. In these illustrative examples, installation bar 1000 may be comprised of a material such as, for example, without limitation, aluminum.

In this depicted example, installation block 800 may be positioned over strip 1004. In this example, strip 1004 may be



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located on surface **1006** of assembly crib **1008**. Installation block **800** may be positioned to be attached to strip **1004** using guard rail **1010** and guard rail **1012** on assembly crib **1008**. As can be seen in this illustrative example, section **902** on flange **818** may contact and/or become attached to strip **1004**. Section **900** on flange **816** and section **904** on flange **820** may not contact strip **1004**.

Turning now to FIG. **11**, an illustration of a top view of an assembly crib is depicted in accordance with an advantageous embodiment. In this illustrative example, installation block **800** may be seen positioned over strip **1004**. Installation block **800** may have width **1101**. Width **1101** may be, for example, without limitation, from around **0.500** to around **0.750** inches.

Additional alignment of installation block **800** may be provided through number of pegs **1100**. In this example, number of pegs **1100** may include peg **1102**, peg **1104**, peg **1106**, and peg **1108**.

In this top view, installation blocks **1112** and **1114** also may be seen. These installation blocks may be positioned using guard rails **1010** and **1012**. In these examples, installation blocks **800**, **1112**, and **1114** may be positioned with a distance of around **2** inches in between each other. In other examples, the installation blocks may be positioned with a different spacing. Additionally, installation block **1112** also may be positioned using installation pegs **1116**, **1118**, **1120**, and **1122**. Installation block **1114** may be positioned using installation pegs **1124**, **1126**, **1128**, and **1130**, and/or other installation pegs.

Once installation blocks, such as installation blocks **800**, **1112**, and **1114**, have been attached to strip **1004**, installation bar **1000** may be attached on top of installation blocks **800**, **1112**, and **1114**. Strip **1004** may then be moved and positioned into the channel using installation blocks **800**, **1112**, and **1114** with installation bar **1000**. In these illustrative examples, additional installation blocks (not shown) may be positioned over strip **1004**. An installation bar, such as installation bar **1000**, also may be attached to these additional installation blocks.

With reference now to FIG. **12**, an illustration of a strip installed into a channel using an installation block is depicted in accordance with an advantageous embodiment. In this illustrative example, installation block **800** may be seen in a side view over joint **1200**.

Joint **1200** may include first skin panel **1202** and second skin panel **1204**. First skin panel **1202** may have first flange **1206**, while second skin panel **1204** may have second flange **1208**. First flange **1206** and second flange **1208** may be attached to support structure **1210**, which may be spar **1212** in these examples. As can be seen, first flange **1206** and second flange **1208** may have step **1214** and step **1216**, which form channel **1218** in this configuration. As can be seen, gap **1220** may be present between first flange **1206** and second flange **1208** within channel **1218**.

Prior to strip **1004** being positioned in channel **1218**, adhesive **1222** may be placed in channel **1218** in lines **1226**, **1228**, and **1230**. As can be seen, line **1228** of adhesive **1222** may cover gap **1220**. In some examples, adhesive **1222** may be placed into gap **1220** to fill gap **1220**.

Additionally, installation block **800** may position strip **1004** such that surface **1248** of strip **1004** may be substantially planar to surface **1232** of first skin panel **1202** and surface **1234** of second skin panel **1204** at position **1205**. Installation block **800** may hold strip **1004** in this position until adhesive **1222** cures. This placement of strip **1004** at position **1205** may be performed through the selection of height **822** for flanges **816**, **818**, and **820**. Section **900** and section **904** of double-sided tape **802** may attach installation

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block **800** to surface **1232** of first skin panel **1202** and surface **1234** of second skin panel **1204**. This may maintain installation block **800** in desired position **1205** while adhesive **1222** cures. Additionally, adhesive **1222** also may be placed in lines **1236** and **1238** and may be applied through gaps **1240** and **1242** in corners **1244** and **1246**.

In this illustrative example, guard rail **1010** and guard rail **1012** may be used to aid in the positioning of strip **1004**. In particular, guard rail **1010** and guard rail **1012** may be used to place installation block **800** in a desired location over channel **1218**.

Turning now to FIG. **13**, an illustration of a top view of a strip installed in a joint is depicted in accordance with an advantageous embodiment. Installation bar **1000** may be removed after flanges **816** and **820** of installation blocks **800**, **1112** and **1114** are attached to the outer surfaces of skin panels **1202** and **1204**. As can be seen in this top view, strip **1004** may be located in channel **1218** and held in place while adhesive **1222** (not shown) cures.

As can be seen in this example, gap **1300** and gap **1302** may be present. Gap **1300** and gap **1302** may have a width from around **0.030** inches to around **0.060** inches in this particular example. Of course, the gaps may vary, depending on the particular implementation. Gaps may be present to take into account thermal expansion of different components. Adhesive **1222** may be placed into gaps **1300** and **1302** during curing of adhesive **1222** in channel **1218**. Adhesive **1222** may be placed into gaps **1300** and **1302** using, for example, without limitation, a syringe and/or some other suitable device.

In these illustrative examples, sections **1304**, **1306**, **1308**, and **1310** may be unsupported by installation blocks **800**, **1112**, and **1114**. Roller **1314** may be moved over one or more of these sections to squeeze down adhesive **1222**. In these examples, additional adhesive **1222** may be added into gaps **1300** and **1302** in channel **1218** to prevent undesirable materials from gathering beneath strip **1004**. In other words, adhesive **1222** may be used to fill and/or seal gaps **1300** and **1302**.

Installation blocks **800**, **1112**, and **1114** may be left in place as illustrated in FIG. **13** until adhesive **1222** sets-up and/or cures to a desired level. Thereafter, installation blocks **800**, **1112**, and **1114** may be removed.

With reference now to FIGS. **14-22**, illustrations of a process for installing a strip are depicted in accordance with an advantageous embodiment. These different figures may illustrate one manner in which a strip, such as strip **344**, may be installed to complete a joint, such as joint **334** in FIG. **3**. This installation may occur, for example, without limitation, during at least one of manufacturing joint **334** and maintenance of joint **334**.

With reference to FIG. **14**, an illustration of a joint in which a strip may be installed is depicted in accordance with an advantageous embodiment. In this illustrative example, joint **1400** may comprise first skin panel **1402** and second skin panel **1404**. First flange **1406** is associated with first skin panel **1402**, and second flange **1408** is associated with second skin panel **1404**.

In this illustrative example, first flange **1406** and second flange **1408** may be attached to support structure **1410**, which may take the form of spar **1412**. First flange **1406** may be secured to spar **1412** using fastener **1414**. Second flange **1408** may be secured to spar **1412** using fastener **1416**.

Gap **1418** may be present between first flange **1406** and second flange **1408** in these examples. Further, step **1420** and step **1422** may be present. This configuration of first skin panel **1402** and second skin panel **1404** may form channel **1424**.



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Masking material **1426**, **1428**, and **1430** may be placed over first skin panel **1402**, gap **1418**, and second skin panel **1404**. First skin panel **1402** and second skin panel **1404** may be covered by masking material **1426** and **1430** to prevent contamination of panel surfaces during processing. Masking material **1428** may prevent adhesive from entering gap **1418**. Width **1432** for masking material **1428** may be selected having a width capable of preventing adhesive from entering gap **1418**.

With reference now to FIG. **15**, an illustration of a channel filled with adhesive is depicted in accordance with an advantageous embodiment. In this illustrative example, adhesive **1500** may be placed into channel **1424**.

Adhesive **1500** may be placed into channel **1424** through a number of different mechanisms. For example, without limitation, a pneumatic seal gun with a wide nozzle may be used to apply adhesive. Further, a plastic sweep or other mechanism may be used to level adhesive within channel **1424**.

With reference next to FIG. **16**, an illustration of adhesive removed from portions of a joint is depicted in accordance with an advantageous embodiment. In this illustrative example, masking material **1426**, **1428**, and **1430** may be removed. In removing masking material **1428**, adhesive **1500** may be removed from section **1600** in channel **1418**. In this illustrative example, adhesive **1500** may be removed from section **1600** prior to removing masking material **1426** and masking material **1430** from first skin panel **1402** and second skin panel **1404**.

Turning to FIG. **17**, an illustration of a strip placed into a channel of a joint is depicted in accordance with an advantageous embodiment. As illustrated in this depicted example, strip **1700** may be placed onto adhesive **1500**. Further, tape **1702** may be used to seal side **1704** of strip **1700** to first skin panel **1402**. Tape **1706** may be used to seal side **1708** of strip **1700** to second skin panel **1404**.

In these illustrative examples, tape **1702** and tape **1706** may take the form of rivet tape. Rivet tape may have two strips of adhesive on the edges of the tape with a center area that has no adhesive.

In these examples, tape **1702** and tape **1706** may be placed onto side **1704** and side **1708** prior to strip **1700** being placed onto adhesive **1500**. Thereafter, tape **1702** may be secured to first skin panel **1402**, and tape **1706** may be secured to second skin pane **1404**.

Turning now to FIG. **18**, an illustration of a caul plate in a vacuum bag placed over a joint is depicted in accordance with an advantageous embodiment. In this illustrative example, caul plate **1800** may be placed on top side **1802** of strip **1700**. Caul plate **1800** also may be taped into place. Further, vacuum bag **1804** may be placed over caul plate **1800** and strip **1700**.

In these illustrative examples, caul plate **1800** may be stiffer along the direction of arrow **1806** as opposed to along a direction perpendicular to joint **1400** at point **1808**. In these illustrative examples, caul plate **1800** may be comprised of an anisotropic material and/or an isotropic material. Examples of anisotropic materials that may be used include, for example, without limitation, a carbon fiber epoxy, wood, and/or other fiber reinforced composite materials. Examples of isotropic materials that may be used include, for example, without limitation, aluminum, steel, metal alloys, and other suitable materials.

Additionally, caul plate **1800** may have width **1810**. Width **1810** may span across a portion of first skin panel **1402**, strip **1700**, and a portion of second skin panel **1404**.

With reference now to FIG. **19**, an illustration of a vacuum applied to a vacuum bag and caul plate is depicted in accordance with an advantageous embodiment. In this illustrative

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example, a vacuum may be drawn on vacuum bag **1804**. This vacuum may be around 25 in-hg to around 27 in-hg in these illustrative examples. The actual vacuum drawn may be selected as one that causes caul plate **1800** to move in the direction of arrow **1900** to force strip **1700** into channel **1424**.

In this manner, caul plate **1800** may push strip **1700** in a manner that first surface **1902** of first skin panel **1402**, second surface **1904** of second skin panel **1404**, and third surface **1906** of strip **1700** are substantially aligned along a plane, including line **1908**.

With this movement in the direction of arrow **1900**, adhesive **1500** may move into gap **1418**. In this illustrative example, end **1910** may be open to the atmosphere to allow movement of adhesive **1500** into gap **1418**. In yet other advantageous embodiments, another end (not shown) opposite end **1406** also may be open to the atmosphere to allow movement of adhesive **1500** into gap **1418**.

This vacuum may be held until adhesive **1500** has set-up and/or cured. In some advantageous embodiments, resistive heating element **1911** may be incorporated into vacuum bag **1804** to accelerate curing of adhesive **1500**.

In this example, gap **1913** may be present between strip **1700** and end **1914** of first skin panel **1402**. Gap **1916** may be present between strip **1700** and end **1918** of second skin panel **1404**.

Turning now to FIG. **20**, an illustration of a vacuum applied to a vacuum bag and a caul plate is depicted in accordance with an advantageous embodiment. In this illustrative example, a view of vacuum bag **1804**, caul plate **1800**, and strip **1700** on first skin panel **1402** is illustrated taken along lines **20-20** as depicted in FIG. **19**. As can be seen in this example, caul plate **1800** has tapered end **2000**. As depicted in this example, tapered end **2000** may be shorter in length than strip **1700**. In this example, length **2002** of tapered end **2000** may be around  $\frac{3}{8}$  of an inch.

In this illustrative example, fastener **2004** and fastener **1414** may be fasteners within number of fasteners **2005**. First flange **1406** associated with first skin panel **1402**, not visible in this view, may be adjacent to flange **2006** in this example. Flange **2006** may be a flange associated with another skin panel not visible in this view.

As depicted in this example, adhesive **1500**, strip **1700**, tape **1702**, and vacuum bag **1804** may stop at end **2008** of first flange **1406**. End **2008** may be adjacent to gap **2010** in this example. Gap **2010** may be the gap between first flange **1406** and flange **2006**. As can be seen in this illustrative example, gap **2010** may be a location at which a joint may be formed between first skin panel **1402** and the other skin panel not visible in this view. Gap **2010** may be filled with an adhesive either prior to or after application of strip **1700**.

With reference now to FIG. **21**, an illustration of a top view of a joint formed by using a strip, a caul plate, and a vacuum bag is depicted in accordance with an advantageous embodiment. As depicted in this illustrative example, joint **1400** may be formed using strip **1700**, caul plate **1800**, and vacuum bag **1804**.

Flanges **1406**, **1408**, and **2006** may not be visible in this view. Fasteners within number of fasteners **2005**, in addition to fastener **1414**, **1416**, and **2004**, may be visible in this view. In this illustrative example, skin panel **1402** may be positioned adjacent to skin panel **2100** with gap **2010**, and skin panel **1404** may be positioned adjacent to skin panel **2102** with gap **2010**. Further, in a manner similar to joint **1400**, joint **2104** may be formed using skin panel **2100**, skin panel **2102**, strip **2106**, and caul plate **2108**.

Turning now to FIG. **22**, an illustration of a completed joint is depicted in accordance with an advantageous embodiment.



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With reference now to FIG. 23, an illustration of a flow-chart for forming a joint is depicted in accordance with an advantageous embodiment. The process in FIG. 23 may be used to form a joint such as, for example, without limitation, joint 334 in FIG. 3, joint 1200 in FIG. 12, and joint 1400 in FIG. 14.

The process may begin by attaching first skin panel 1202 and second skin panel 1204 to support structure 1210 (operation 2300). In these examples, these skin panels may be attached by attaching first flange 1206 for first skin panel 1202 and second flange 1208 for second skin panel 1204 to support structure 1210 using plurality of fasteners 342. The process may then bond strip 1004 in channel 1218 to form joint 1200 (operation 2302), with the process terminating thereafter. In this manner, joint 1200 may have desired state 345 of boundary layer 347 of fluid flow 306. In these examples, fluid flow 306 may take the form of airflow 308, and desired state 345 of airflow 308 in boundary layer 347 may be laminar airflow 310.

Turning next to FIG. 24, an illustration of a flowchart for performing maintenance on a joint is depicted in accordance with an advantageous embodiment. The process in FIG. 24 may be used to perform maintenance on a joint such as, for example, without limitation, joint 334 in FIG. 3, joint 1200 in FIG. 12, and joint 1400 in FIG. 14.

The process may begin by removing strip 1004 from channel 1218 (operation 2400). Thereafter, adhesive 1222 also may be removed from channel 1218 (operation 2404). Thereafter, a number of maintenance operations may be performed on joint 1200 (operation 2406). These operations may include, for example, without limitation, replacing at least one of first skin panel 1202 and second skin panel 1204, painting at least one of first skin panel 1202 and second skin panel 1204, replacing plurality of fasteners 342, and/or other suitable maintenance operations. Thereafter, the process may then bond strip 1004 in channel 1218 to reform joint 1200 (operation 2408), with the process terminating thereafter.

Turning now to FIG. 25, an illustration of a process for preparing a strip for bonding in a channel is depicted in accordance with an advantageous embodiment. The process illustrated in FIG. 25 may be implemented using installation block 800 in FIG. 8 and assembly crib 1008 in FIG. 10.

The process may begin by placing double-sided tape 802 onto side 804 of installation block 800 (operation 2500). Next, the process may form slit 810 and slit 812 in double-sided tape 802 (operation 2502). Then, double-sided tape 802 may be wrapped around the corners of flanges 816, 818, and 820 on installation block 800 (operation 2504), with the process terminating thereafter. In these examples, section 900 of double-sided tape 802 may be wrapped around corners 906 and 908 for flange 816. Section 902 of double-sided tape 802 may be wrapped around corners 910 and 912 for flange 818. Section 904 of double-sided tape 802 may be wrapped around corners 914 and 916 for flange 820 in installation block 800.

With reference now to FIG. 26, an illustration of a flow-chart for attaching a strip to an installation block is depicted in accordance with an advantageous embodiment. The process illustrated in FIG. 26 may be implemented as part of a process for bonding strip 1004 in channel 1218 as depicted in FIG. 12, which may be one implementation of operation 2302 in FIG. 23 for bonding strip 344 in channel 336.

The process may begin by placing strip 1004 in assembly crib 1008 (operation 2600). Thereafter, installation block 800 may be positioned over strip 1004 (operation 2602). Installation block 800 may then be placed onto strip 1004 such that section 902 of double-sided tape 802 on flange 818 may become attached to strip 1004 (operation 2604). A determi-

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nation may be made as to whether additional installation blocks are to be attached to strip 1004 (operation 2606).

If additional installation blocks are to be attached, the process returns to operation 2602. A number of installation blocks may be attached to strip 1004 in this manner. If additional installation blocks are not to be attached to strip 1004, installation bar 1000 may be attached to installation block 800 (operation 2606), with the process terminating thereafter. In other words, installation bar 1000 may be attached to installation blocks 800, 1112, and 1114 in these illustrative examples. Thereafter, strip 1004, the number of installation blocks, and installation bar 1000 may be ready for use to install strip 1004 in channel 1218.

With reference now to FIG. 27, an illustration of a flow-chart of a process for positioning a strip in a channel for bonding is depicted in accordance with an advantageous embodiment. This process may be used in bonding strip 1004 in channel 1218 as depicted in FIG. 12. This process may be one implementation of the process in operation 2302 in FIG. 23 above.

The process may begin by placing adhesive 1222 into channel 1218 (operation 2700). The process may then position strip 1004 relative to channel 1218 using installation blocks 800, 1112, and 1114, which are attached to strip 1004 (operation 2702).

The assembly of installation block 800, installation block 1112, and installation block 1114, as attached to strip 1004 and installation bar 1000, may then be manipulated by a human operator to place strip 1004 into channel 1218 onto adhesive 1222 (operation 2704). This positioning of the installation blocks may provide a desired positioning of strip 1004. The positioning of the installation blocks also may be performed using guard rails 1010 and 1012. In other words, the installation blocks enable precise matching of surface 1232 of first skin panel 1202, surface 1234 of second skin panel 1204, and surface 1248 of strip 1004 in a desired configuration.

The process may then press down on the installation blocks (operation 2706). By pressing down on installation blocks 800, 1112, and 1114, flanges 816 and 820 may be firmly attached to surface 1232 of first skin panel 1202 and surface 1234 of second skin panel 1204. Thereafter, installation bar 1000 may be removed (operation 2708). Roller 1314 may then be run over the sections of strip 1004 between installation blocks 800, 1112, and 1114 to squeeze down adhesive 1222 (operation 2710). In these illustrative examples, these sections may be, for example, without limitation, sections 1304, 1306, 1308, and 1310.

The process may then add adhesive 1222 to gaps 1240 and 1242 at corners 1244 and 1246 associated with channel 1218, respectively (operation 2712). In one advantageous embodiment, adhesive 1222 may be added using a syringe. In other advantageous embodiments, a different type of sealant may be used in the place of adhesive 1222.

The process may then cure the adhesive (operation 2714). Adhesive 1222 may function as a shim once adhesive 1222 has been cured. In this manner, strip 1004 may be maintained in the desired position. The corners of the channel are filled with adhesive/sealant injected by means of a syringe. Thereafter, installation blocks 800, 1112, and 1114 may be removed (operation 2716), with the process terminating thereafter.

Maintenance on joint 1200 may be performed by removing strip 1004 from joint 1200. Other operations also may be performed. Afterwards, strip 1004 or a new strip may be bonded into channel 1218 in the manner described in FIG. 27.



Turning now to FIG. 28, an illustration of a flowchart of a process for bonding a strip in a channel is depicted in accordance with an advantageous embodiment. This process may be used to bond strip 1700 into channel 1424 to form joint 1400. This process may be a more-detailed illustration of operation 2302 in FIG. 23 above.

The process may begin by placing masking material 1426, 1428, and 1430 on first skin panel 1402, second skin panel 1404, and gap 1418 in channel 1424 (operation 2800). Thereafter, adhesive 1500 may be placed into channel 1424 (operation 2802). Adhesive 1500 and masking material 1428 may be removed prior to placing strip 1700 into channel 1424 (operation 2804). Adhesive 1500 and masking material 1428 may be removed to expose gap 1418 within channel 1424.

Next, strip 1700 may be placed into channel 1424 (operation 2806). Tape 1702 may be used to secure side 1704 of strip 1700 to first skin panel 1402, and tape 1706 may be used to secure side 1708 of strip 1700 to second skin panel 1404 (operation 2808). Caul plate 1800 may then be placed over strip 1700 (operation 2810). Additionally, vacuum bag 1804 may be placed over caul plate 1800 and strip 1700 (operation 2812). Operation 2812 may involve securing vacuum bag 1804 around caul plate 1800.

The process may then apply a vacuum to caul plate 1800 through vacuum bag 1804 (operation 2814). With this vacuum, caul plate 1800 may push strip 1700 into channel 1424 in a manner such that first surface 1902 of first skin panel 1402, second surface 1904 of second skin panel 1404, and third surface 1906 of strip 1700 may be substantially aligned along a plane. This alignment may allow for desired state 345 for fluid flow 306. The process may then maintain the vacuum until adhesive 1500 has cured (operation 2816). Thereafter, caul plate 1800 and vacuum bag 1804 may be removed (operation 2818). Tape 1702 and tape 1706 also may then be removed (operation 2820). Any residual amount of adhesive 1500 may then be removed (operation 2822), with the process terminating thereafter.

The flowcharts and block diagrams in the different depicted embodiments illustrate the architecture, functionality, and operation of some possible implementations of apparatus and methods in different advantageous embodiments. In this regard, each block in the flowcharts or block diagrams may represent a module, segment, function, and/or a portion of an operation or step.

In some alternative implementations, the function or functions noted in the blocks may occur out of the order noted in the figures. For example, in some cases, two blocks shown in succession may be executed substantially concurrently, or the blocks may sometimes be executed in the reverse order, depending upon the functionality involved.

For example, operation 2300 in FIG. 23 may be replaced with an operation in which the strip is removed or maintenance is performed on the joint prior to performing operation 2302.

Thus, the different advantageous embodiments may provide a method and apparatus for a joint for a surface of a platform. In these examples, an apparatus may have a first skin panel having a first surface, a second skin panel having a second surface, a first flange located at the end of the first skin panel, a second flange located at the end of the second skin panel, and a strip having a third surface.

The first skin panel may be located adjacent to the second skin panel such that the first flange and the second flange form a channel. The strip may be bonded in the channel. This location of the strip and channel may be such that fluid flow over the third surface of the strip, the first surface of the first

skin panel, and the second surface of the second skin panel may have a desired boundary layer state.

The different advantageous embodiments may provide a capability to generate airflow at a substantially desired state at the boundary layer. For example, the desired state at the boundary layer may be a substantially laminar airflow over the surface of an aircraft.

The description of the different advantageous embodiments has been presented for purposes of illustration and description, and it is not intended to be exhaustive or limited to the embodiments in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art. Further, different advantageous embodiments may provide different advantages as compared to other advantageous embodiments.

Although the different advantageous embodiments have been described with respect to aircraft, the different advantageous embodiments may be applied to other types of platforms. For example, without limitation, other advantageous embodiments may be applied to a mobile platform, a stationary platform, a land-based structure, an aquatic-based structure, a space-based structure, and/or some other suitable object in which fluid flow may be present. More specifically, the different advantageous embodiments may be applied to, for example, without limitation, a submarine, a bus, a personnel carrier, a tank, a train, an automobile, a spacecraft, a surface ship, and/or some other suitable object.

The embodiment or embodiments selected are chosen and described in order to best explain the principles of the embodiments, the practical application, and to enable others of ordinary skill in the art to understand the disclosure for various embodiments with various modifications as are suited to the particular use contemplated.

What is claimed is:

1. A method for forming a joint, the method comprising:
  - attaching a first skin panel and a second skin panel to a support structure, in which the first skin panel has a first surface and a first flange located at an end of the first skin panel, the second skin panel has a second surface and a second flange located at an end of the second skin panel, and the first flange and the second flange are positioned to form a channel; and
  - bonding a strip having a third surface in the channel to form the joint, in which a fluid flow over the first surface, the second surface, and the third surface has a desired state, the strip substantially occupying the channel such that fluid flow passes substantially over the first surface of the first skin, the second surface of the second skin, and the third surface of the strip and is restricted from flowing under the first skin, the second skin, and the strip.
2. The method of claim 1, wherein the attaching step comprises:
  - attaching the first flange and the second flange to the support structure with a plurality of fasteners.
3. The method of claim 1, wherein the bonding step comprises:
  - bonding the strip in the channel with an adhesive to form the joint, wherein the flow of fluid over the first surface, the second surface, and the third surface has the desired state at a boundary layer.
4. The method of claim 1, wherein the bonding step comprises:
  - placing an adhesive on a surface of the channel;
  - positioning the strip in the channel to contact the adhesive such that the third surface of the strip is positioned relative to the first surface of the first skin panel and the second surface of the second skin panel, wherein the



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flow of fluid over the first surface, the second surface, and the third surface has the desired state at a boundary layer; and

curing the adhesive to bond the strip in the channel.

**5.** The method of claim **1** further comprising:

attaching the strip to a number of installation blocks;

placing an adhesive in the channel; and

positioning the strip with the number of installation blocks in the channel to contact the adhesive in the channel such that a third surface of the strip is positioned relative to the first surface of the first skin panel and the second surface of the second skin panel, wherein the flow of fluid over the first surface, the second surface, and the third surface has the desired state at a boundary layer.

**6.** The method of claim **5**, wherein the step of positioning the strip with the number of installation blocks in the channel to contact the adhesive in the channel such that the third surface of the strip is positioned relative to the first surface of the first skin panel and the second surface of the second skin panel comprises:

placing the number of installation blocks over the channel to position the strip with the number of installation blocks in the channel to contact the adhesive in the channel such that the third surface of the strip is in a desired position relative to the first surface of the first skin panel and the second surface of the second skin panel.

**7.** The method of claim **6**, wherein the number of installation blocks each has a first flange, a second flange, and a third flange, wherein the second flange of the each installation block attaches to the strip and wherein the first flange of the each installation block contacts the first surface of the first skin panel and the third flange of the each installation block contacts the second surface of the second skin panel such that the third surface of the strip is in the desired position.

**8.** The method of claim **5**, wherein the step of attaching the strip to the number of installation blocks comprises:

placing a double-sided adhesive tape on a first side of the number of installation blocks; and

attaching the strip to the double-sided adhesive tape on the first side of the number of installation blocks.

**9.** The method of claim **8**, wherein the strip is attached to the double-sided adhesive tape on the first side of the number of installation blocks using an assembly crib with a plurality of guard rails and a plurality of pegs.

**10.** The method of claim **1**, wherein the support structure is selected from one of a spar, a frame, a stringer, a clip, and a rib.

**11.** The method of claim **1**, wherein the first skin panel and the second skin panel are comprised of a material selected from one of aluminum, steel, titanium, and a composite material.

**12.** The method of claim **1**, wherein the strip is comprised of a material selected from one of aluminum, steel, titanium, and a composite material.

**13.** The method of claim **6**, wherein the number of installation blocks are moved using a number of installation bars attached to the number of installation blocks.

**14.** The method of claim **5** further comprising:

placing additional adhesive into a first gap between the strip and the first skin panel and into a second gap between the strip and the second skin panel.

**15.** The method of claim **1**, wherein the step of bonding the strip having the third surface in the channel to form the joint in which the fluid flow over the first surface, the second surface, and the third surface has the desired state comprises:

placing the strip on an adhesive on a surface of the channel;

placing a caul plate over the strip; and

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applying a vacuum to the caul plate, wherein the caul plate pushes the strip downward into the channel such that the fluid flow over the first surface, the second surface, and the third surface has a desired state.

**16.** The method of claim **15** further comprising:

covering the caul plate placed over the strip with a vacuum bag prior to applying the vacuum.

**17.** The method of claim **15** further comprising:

placing the adhesive on the surface of the channel.

**18.** The method of claim **15** further comprising:

placing a masking material on the first skin panel, on the second skin panel, and over a gap in the channel;

placing an adhesive into the channel after placing the masking material on the first skin panel, on the second skin panel, and over the gap in the channel; and

removing the adhesive and the masking material over the gap in the channel prior to placing the strip on the adhesive.

**19.** A method for forming a joint on an aircraft, the method comprising:

attaching a first skin panel and a second skin panel to a spar, in which the first skin panel has a first surface and a first flange located at an end of the first skin panel, the second skin panel has a second surface and a second flange located at an end of the second skin panel, the first flange and the second flange are positioned to form a channel, and the first skin panel and the second skin panel are comprised of a material selected from one of aluminum, steel, titanium, and a composite material;

placing a double-sided adhesive tape on a first side of a number of installation blocks, in which the number of installation blocks each has a first flange, a second flange, and a third flange;

attaching a strip to the double-sided adhesive tape on the first side of the number of installation blocks, in which the strip is comprised of a material selected from one of aluminum, steel, titanium, and a composite material;

attaching the strip to the double-sided adhesive tape on the first side of the number of installation blocks using an assembly crib with a plurality of guard rails and a plurality of pegs;

placing an adhesive in the channel;

attaching the number of installation blocks to the first surface of the first skin panel and the second surface of the second skin panel over the channel to position the strip with the number of installation blocks in the channel to contact the adhesive in the channel such that a third surface of the strip is in a desired position relative to the first surface of the first skin panel and the second surface of the second skin panel, in which the second flange of the each installation block attaches to the strip, and in which the first flange of the each installation block contacts the first surface of the first skin panel and the third flange of the each installation block contacts the second surface of the second skin panel such that the third surface of the strip is in the desired position; and curing the adhesive to bond the strip in the channel to form the joint.

**20.** A method for forming a joint on an aircraft, the method comprising:

attaching a first skin panel and a second skin panel to a spar, in which the first skin panel has a first surface and a first flange located at an end of the first skin panel, the second skin panel has a second surface and a second flange located at an end of the second skin panel, the first flange and the second flange are positioned to form a channel, and the first skin panel and the second skin panel are

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comprised of a material selected from one of aluminum, steel, titanium, and a composite material;  
placing a masking material on the first skin panel, on the second skin panel, and over a gap in the channel;  
placing an adhesive into the channel after placing the masking material on the first skin panel, on the second skin panel, and over the gap in the channel;  
removing the adhesive and the masking material over the gap in the channel prior to placing a strip on the adhesive;

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placing the strip on the adhesive on a surface of the channel;  
placing a caul plate over the strip;  
covering the caul plate placed over the strip with a vacuum bag prior to applying a vacuum; and  
applying the vacuum to the caul plate, in which the caul plate pushes the strip downward into the channel such that a fluid flow over the first surface and the second surface has a desired state.

\* \* \* \* \*